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The emotional connotations of major versus minor tonality: One or more origins?

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Abstract

The association between major/minor tonality and positive/negative emotional valence is psychologically robust, but without a single accepted explanation. I compare six partially related theories. *Dissonance*: On average, passages in minor keys are more dissonant because, on average, the minor triad is more dissonant (rougher, less harmonic) or because tonal structure is more complex. *Alterity and markedness*: Major triads and scales are more common than minor, and positive valence is more common than negative. Major and positive valence are the norm; minor and negative are marked Others. *Uncertainty*: The minor triad has a more ambiguous (less salient) root than the major, and the minor scale has more variable form and a more ambiguous (less stable) tonic; uncertainty is associated with anger, sadness, distress, and grief. *Speech*: By comparison to major triads and scales, minor contain pitch(es) that are lower than expected – just as sad speech is lower than expected. *Salience*: In diatonic chord progressions, flattened diatonic scale degrees are more salient than sharpened because their harmonics better match the prevailing scale. Scale degrees 3 and 6 are more likely to destabilize tonality in minor than major tonalities. *Familiarity*: Arbitrary emotional differences between major and minor were reinforced in a historical process of cultural differentiation. For each theory, there are credible arguments and evidence for and against. All theories are broadly consistent with Terhardt's pattern-recognition model of pitch perception (non-musical perceptual familiarity with the harmonic series), Schenker's concept of prolongation (specifically, tonal voice leading as a prolongation of the tonic triad), evolutionary explanations of the emotional connotations of alterity, and a psychohistory of tonality in which melody, polyphony, leading tones, and the major–minor system emerged at different times, explicable by different psychological principles.

Keywords

emotion, leading tone, major, minor, pitch, prolongation, salience, speech, uncertainty, Schenker, music and evolution

The association in Western tonal music between emotional valence (positive versus negative) and music-structural factors such as tempo (fast versus slow), mode (major versus minor tonality), and (to a lesser extent) consonance/dissonance is well established in music

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psychology, but clear explanations are lacking. Is there something about the structure of major and minor scales and typical passages in major and minor keys that may have produced these emotional connotations?

The research literature on this question does not consider all emotions, but focuses on those positively and negatively valenced emotions that are typically expressed by pure music (music without text or program) in the Western tonal tradition. The words that are used to identify emotions may have unclear definitions or boundaries and may differ from one culture to the next, so claims about the meanings and origins or specific emotions (represented by words) may be problematic. While many musical emotions belong to a small number of main categories – Juslin and Persson (2002) listed happiness, sadness, anger, fear and tenderness – there are many more emotion words in common use, and they often partially overlap. In a qualitative approach based on interviews, Gabrielsson and Lindström Wik (2003) listed the following emotions evoked by music: peace, harmony, safety, warmth, humility, wonder, awe, reverence, respect, joy, love, perfection, rapture; and loneliness, longing, melancholy, embarrassment. In a quantitative rating study, Zentner, Grandjean, and Scherer (2008) isolated the following factors: wonder, transcendence, tenderness, nostalgia, peacefulness, power, joyful activation, tension and sadness. In both cases, positive emotions clearly outnumbered negative, suggesting that music more often has positive valence. I will return to this point under the heading of "alterity".

In general, fast tempos are associated with positive emotions and slow tempos with negative emotions (Rigg, 1940). In typical tonal musical excerpts, tempo may have a stronger effect on emotional valence than major or minor mode (Gagnon & Peretz, 2003), so for example a Hungarian folk melody may sound happy because of its rhythm and tempo – in spite of its minor tonality. The tempo effect may be a consequence of arousal, but it is not a straightforward consequence: in anger, high arousal is associated with negative emotion, whereas in tenderness, low arousal is associated with positive emotion. The relationship between tempo and valence can be explained in terms of arousal if happiness and sadness are perceived as inherently more salient than anger and tenderness. This is plausible if we spend more time during our lives experiencing happiness or sadness than experiencing anger or tenderness.

Positive emotional valence in music can also be associated with rising pitch: Garardi and Gerken (1995) observed positive responses to rising pitch in college students but not in children aged 5 or 8 years. On that basis one might expect a tendency for pitch to rise in happy speech and to fall in sad speech; but in a study of vocal expression in speech and music, Juslin and Laukka (2003) instead found that both rising and falling contours could be associated with both positive and negative emotions (rising contours are typical of anger, fear and joy, while falling contours are typical of sadness and tenderness). Moreover, there is little evidence for a vocabulary of contour shapes corresponding to different emotions (Bänziger & Scherer, 2005).

The psychological association of major and minor tonalities in Western music with positive and negative valence is quite robust. Hevner (1935, 1936) confirmed that listeners, regardless of training, consistently ascribed labels indicative of positive emotional valence to music in major keys and negative to minor. Kastner and Crowder (1990) reported that children aged 3–12 years reliably associated major tonalities with positive emotion (happy, contented) and minor tonalities with negative emotion (sad, angry); results depended on whether the melodies were accompanied with chord progressions, suggesting an association between negative emotion and acoustic dissonance.

Emotional responses to music generally involve physiological changes (Krumhansl, 1997), but it is unclear whether physiology can explain the origin of the associations (Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008). Psychological explanations are similarly problematic because of the large number of possible emotions and different ways of organizing them. Osgood, Suci, and Tannenbaum (1957) classified the emotional meaning of words along three dimensions: valence (evaluation), arousal (activation) and potency (dominance). In a two-dimensional space of valence versus arousal, Russell (1980) constructed a circumplex model of affect with eight categories arranged in a circle: pleasure, excitement, arousal, distress, displeasure, depression, sleepiness and relaxation. In purely categorical models, emotions can be classified according to their evolutionary functions and neurobiological underpinnings; examples include expectancy, rage, fear and panic (Panksepp, 1998).

There is a developmental progression in the relationship between mode and emotion that is consistent with cultural learning. For unaccompanied melodies, Gregory, Worrall, and Sarge (1996) found that children aged 7–8 years heard unaccompanied major tunes as happy and minor as sad, whereas children aged 3–4 years did not. Dalla Bella, Peretz, Rousseau, and Gosselin (2001) prepared excerpts of real music by composers such as Verdi and Albinoni that were played on piano and manipulated with respect to mode and tempo, and asked listeners to judge whether each passage was sad or happy; they found that 6–8-year-olds and adults took into account both tempo and mode, but 5-year-old children responded only to tempo and ignored mode. Similarly, Garardi and Gerken (1995) found that affective responses to mode in 8-year-olds but not in 5-year-olds.

Cazden (1945) argued that that the perception of consonance and dissonance is conditioned by exposure to music within styles and cultures. Given that the detailed content of musical styles and cultures is always to some extent arbitrary, the "rules" of consonance and dissonance in Western music may be similarly arbitrary. Does the same apply to the emotional connotations of major and minor keys? If so, the psychological question of the origin of the connotations is reduced to a historical question: Why did Western music develop such that major tonalities were usually associated with positive emotions and minor with negative? If the association is an accident of history, Western culture could have evolved in exactly the opposite way. Is that conceivable? If there are clear reasons for the association, we should be able to isolate them by systematically comparing and evaluating different theoretical explanations.

In the remainder of this article, I will address these issues in three stages. First, I will consider some relevant general theoretical approaches to music perception. Against that background, I will then present some promising theories of the origin of the emotional connotations of major and minor tonalities. Finally, I will evaluate and compare the theories.

Theoretical background

In this section, I consider four broad approaches to music perception and their possible relevance for the emotional connotations of major and minor keys. First, Terhardt's pattern-recognition model of pitch perception assumes that the harmonic series is familiar to the auditory system; environmental harmonic complex tones such as voiced speech sounds evoke spectral pitch patterns that correspond approximately to the harmonic series. Second, Schenker's concept of contrapuntal prolongation is consistent with the idea that a major-minor passage can be perceived as a prolongation of its tonic triad. Third, the discipline of evolutionary psychology can explain the difference between positive and negative emotions in terms of their functions in promoting survival and reproduction. Fourth, the psychohistory of tonality is a music history based on cognitive principles underlying tonal musical structure; it assumes that these principles were gradual internalized as musical language developed.

Psychoacoustics of pitch perception

Since Rameau, it has been clear that the difference between major and minor triads involves pitch patterns that are related to the spectra of individual complex tones in our non-musical environment. That suggests a possible role for modern theories of non-musical pitch perception in explaining the perception of major and minor triads and tonalities. Given the lack of a widely accepted theory of pitch perception, I will briefly present a suitable approach as a foundation for this article.

The basilar membrane in the inner ear performs a kind of running spectrum analysis on all sound, regardless of what produced it. Both peripherally and centrally, temporal and spectral processing are inextricably mixed. Together, they enable us to perceive several partials (or pure-tone components) within a complex sound. Even if we do not hear the partials consciously, information about them passes along the auditory nerve to the brain and affects our experience of sound (e.g. timbre).

To understand everyday speech, we must understand both its lexical content and its prosody. Prosody includes changes in pitch, loudness, timbre and duration of individual phonemes. The pitch contour of typical speech (its ups and downs) carries important information such as the speaker's intention or evaluation of what is being said.

Speech is normally heard in noisy environments. The auditory system has evolved to enable listeners to ignore background noise and focus on what we want to hear (the "signal"). Pure tones that start, end and/or change simultaneously are likely to be partials of a single tone, so they are linked perceptually to one sound source. Similarly, partials whose frequencies correspond approximately to a harmonic series are likely to be part of a harmonic complex tone such as a voiced speech sound (Bregman, 1990).

The auditory system is constantly "trying" to identify harmonic pitch patterns in order to "decide" which pure tones are parts of which complex tone. The relevant neural networks for pitch are difficult to study because they involve very large numbers of empirically inaccessible neurons that process information in the time and frequency domains simultaneously. For present purposes, we need only understand the basic principles that relate input to output, input being the running spectrum produced by the basilar membrane, and output being perceived fundamental frequency, for example of a speech signal. Beyond that, Hebbian learning, developmental plasticity, and the importance of physiological flexibility for the survival and reproduction of humans in diverse and changing environments imply that this input-output relationship depends more on environmental affordances (E. J. Gibson, 2000; J. J. Gibson, 1966) than on any physiological constraints.

Neural networks that track the harmonic series in speech perception produce an output for any sonic input. For a non-harmonic spectrum, the output is some kind of best fit between the incoming perceptible spectrum and a harmonic series (Terhardt, 1974). If the spectrum is harmonic with missing fundamental, the output may correspond to the fundamental. If the incoming spectrum includes three or four overlaid harmonic series, as in a typical musical chord, and it is not clear which partial corresponds to which fundamental, the output will be those pitches that are most likely to be fundamental frequencies on the basis of the available information (which includes musical experience). Those pitches are not necessarily the same as the original fundamentals.

The perceptual salience of chord tones depends on the relative intensity of the tones and the intervals between them; on average, the conventional root is more salient, because the root tends to have more audible harmonic partials above it than the other tones of a chord. Chords also evoke non-notated pitches at missing fundamentals. On this basis, it possible to predict

(Parncutt, 1988) and measure (Parncutt, 1993) the pitch salience profile of any chord, averaged over diverse typical inversions, registers, spacings and doublings.

These arguments deliberately ignore questions of tuning. Harmonics within complex tones can be mistuned by about a quartertone (50 cents) without being separately perceived, or significantly affecting pitch salience at the fundamental (Moore, Glasberg, & Peters, 1983; Terhardt, Stoll, & Seewann, 1982). The empirical literature (e.g. Burns & Ward, 1978) suggests that mistunings of the order of a quartertone commonly go unnoticed in high-level music performances (for example, in fast, complex passages). In a sustained chord of non-vibrato tones, mistuning of a quartertone clearly sounds dissonant, but the mistuned tone does not stop contributing to the salience of pitches at missing fundamentals. It follows that theories of tuning based on frequency ratios are misleading unless numerical uncertainty is systematically considered.

The major triad looks like part of the harmonic series: harmonic numbers 3, 4 and 5 (2nd inversion); 4, 5, and 6 (root position); or 5, 6 and 8 (first inversion). The same applies to a major-minor 7th chord; the difference between the "harmonic" ("natural", "septimal") minor 7th (7:4, 969 cents) and the minor seventh in 12-tone equal temperament (1000 cents) lies within the tuning tolerance of the auditory system for recognizing harmonic patterns. Most other commonly heard chords, including the minor triad, are mixtures of tones that match part of a harmonic series above the root and tones that do not – just as some partials in the spectrum of a typical church bell are close to harmonics of the strike tone, while others are not.

Terhardt's theory predicts that the minor triad has a more ambiguous root than the major triad. According to the simple algorithm of Parncutt (1988), as later revised (Parncutt, 1993, 1997, 2009, 2011; see also Parncutt & Bregman, 2000), when the minor triad is presented in many different possible inversions, registers, spacings and doublings, the most salient pitch is the conventional root. But the difference in salience between the most salient and second-most salient pitch is smaller than for the major triad, so the main pitch or root of the minor triad is more ambiguous. The second possible root corresponds to the minor 3rd; other possible roots are virtual, corresponding to the 4th and minor 6th above the conventional root. The C-minor triad (C E♭ G) typically evokes or implies pitches at C, E♭, G and F/A♭, in that order of salience (Parncutt, 2009, appendix). Similarly, the C-major triad CEG evokes pitches at C, G/E, A and F. In musical contexts, the salience of these pitches also depends on relative intensity, voicing, and masking.

Are these missing fundamentals really perceived? Musicians do not perceive them in an ear-training test unless they "make a mistake", and it is difficult to explore the musical pitch perception of non-musicians due to the noisiness of their responses in pitch-perception experiments (Reichweger, 2010). But we often perceive without awareness (Merikle, Smilek, & Eastwood, 2001) and unconscious information regularly affects social behavior (Neuberg, 1988); in the ecological "direct perception" approach of Gibson (1966), awareness is merely a byproduct of perception. If we assume that the auditory system is constantly looking for harmonic patterns among partials, as it does when processing a speech signal in a noisy environment, we can predict where missing fundamentals might be perceived, and estimate the probability of consciously perceiving or noticing them (Parncutt, 1989, Terhardt et al., 1982). These predictions can be compared with significant peaks in empirical profiles of goodness-of-fit judgements, and differences in salience can also be empirically tested (Parncutt, 1993; Reichweger, 2010). For example, the pitch model of Parncutt (1988) predicts that the 3rd of a minor triad is more salient than the 5th; Krumhansl and Kessler (1990) obtained strikingly higher mean ratings for the 3rd degree of the minor scale than for the 5th scale degree, a finding that contradicted predictions based on music theory (the cycle of 5ths or the tonal pitch space model of Lerdahl, 1988).

Terhardt's algorithm has been criticized for its neglect of the relative phase of partials within a monaural signal (Meddis & Hewitt, 1991; Moore & Peters, 1992). Evidence for the effect of monaural phase differences on pitch is confined to artificial sounds (e.g. Patterson, 1973). Monaural phase differences do not affect the perceived pitch of typical natural sounds, presumably because monaural phase differences carry little or no reliable information about sound sources in real human environments; reflectors (including the ground) tend to shuffle phase relations, but they have less effect on amplitudes, and no effect on frequencies (Terhardt, 1988). Thus, spectral frequencies are the most reliable carries of information about sound sources, followed by spectral amplitudes. In typical environments, monaural phase information only carries reliable information about sound sources during the first few tens of milliseconds, before direct sound is overlaid by reflected sound. This fundamental ecological constraint on pitch perception evidently influenced the evolution of the auditory system.

More generally, Terhardt's theory has been criticized for neglecting research on the physiology of auditory pathways and the temporal basis of pitch coding in the auditory system (Ebeling, 2007; Fricke, 2010; Hesse, 1993; Tramo, Cariani, Delgutte, & Braida, 2001). For the present purpose, the underlying physiology is not directly relevant. My focus is instead on pitch as subjective experience – in particular, as musical experience. Moreover, physiologically based models such as Leman (2000) do not necessary make quantitatively superior predictions for the pitches evoked by complex sounds and their salience. Terhardt merely modeled the relationship between input and output on the basis of psychoacoustic data and models, where input is the spectrum of a steady state sound and output is a set of possible pitches and their salience.

The pitches that we perceive in tonal music are mainly fundamentals of incomplete harmonic pitch patterns of spectral pitches; isolated spectral pitches (pure tones) are rarely heard consciously. The brain locates those fundamentals from the audible partials in a running spectrum by recognizing pitch patterns that correspond approximately to harmonic patterns that are normally audible in speech phonemes (whereby lower harmonics are generally more important, because more often audible). This process is enabled by neural networks and may be largely learned by exposure to speech. This theory can explain why the root of the minor triad is more ambiguous than the root of the major triad; Parncutt (2011) argued in addition that the pitch profiles of major and minor triads determine the stability profiles of major and minor keys respectively (the key profiles of Krumhansl & Kessler, 1982).

Prolongation of the tonic triad

Schenker (1923) applied the concept of prolongation to different hierarchical levels of musical structure. In his original (Austrian) writings, he used the term *Auskomponierung* – the composing-out of a musical structure. At the highest or longest-term level of musical structure, he applied the concept to whole pieces or movements: a piece is a prolongation of the *Ursatz*, which in turn is a prolongation of the tonic triad.

Schenker's theory was not intended as a theory of perception, but aspects of it have interesting psychological implications. One such aspect is the idea that a passage of tonal music, or merely a short melody, may be regarded as a prolongation of its tonic triad (Parncutt, 2012). In making this claim, I ignored central aspects of Schenkerian theory, including considerations of octave register; the main reason for mentioning the name "Schenker" was to acknowledge the origin of the idea. I considered only the short-term prolongation of the tonic triad as a pc-set or

Tn-type (cf. Rahn, 1980), and I considered register only in the sense that root-position triads are more common than inversions (Eberlein, 1994); surprisingly many tonal melodies can be understood as prolongations of a root-position tonic triad. This concept of prolongation is a radical oversimplification of Schenkerian theory and analysis, in which the hierarchical structure of a musical work is paramount. But it is a promising idea in a music-psychological approach that focuses on the perception of simpler, experimentally accessible structures such as melodies or fragments falling within the psychological present. The cognitive processing of harmonic cadences occurs primarily at a local level, by comparison to global processing of over longer time periods (Tillmann, Bigand, & Madurell, 1998). I am not addressing the Schenkerian idea that an entire piece can be considered a prolongation of a single Ursatz.

In Schenkerian theory (e.g. Forte & Gilbert, 1982), a composer can prolong a triad by repeating its tones (e.g. as an arpeggio) or by playing tones that are adjacent to chord tones in the prevailing scale. The major triad is the most common triad in mainstream Western music, and the root position is its most common inversion (Eberlein, 1994). The chord C4 E4 G4 can be prolonged by melodies that comprise the tones B3, C4, D4, E4, F4, G4 or A4, and chromatic alterations of these tones. Expressed relative to the tonic, the triad 1-3-5 can be prolonged by melodies that include the tones 7-1-2-3-4-5-6 – all within one octave register. The range can be extended beyond one octave by adding the most stable scale degrees outside this range – the lower dominant and upper tonic – to create the pattern 5-7-1-2-3-4-5-6-1. Many well-known folk melodies, children's songs, and national anthems, as well as classical works such as Bach fugues and Mozart sonatas, are consistent with this stereotype (Parncutt, 2012).

According to Salzer (1952/1962, p. 16), the function of "contrapuntal chords" is to

> prolong and elaborate [a] single harmony or chord ... The fact that the space between two chords may be prolonged and that various chords may serve to prolong one single chord, was a most important discovery which had its origin in the music of the Middle Ages.

While Salzer's analyses of early music have been criticized as anachronistic (Judd, 1985), the general idea of prolongation, when combined with music-theoretical ideas from the historical period in question, can clarify both surface-level and deeper structures in modal counterpoint (Stern, 1990) – suggesting that the idea of prolongation can provide insight into the structure and perception of any kind of tonal music.

That being the case, psychologists may ask: To what extent is the prolonged harmony or structure psychologically real? Do people really perceive tonal music this way? Does a prolonged tonic triad really exist in the background of a piece of music in a major or minor key? Is the strong correlation (Parncutt, 2011) between the pitch-salience profile of the tonic triad (Parncutt, 1988) and the goodness-of-fit (stability) profiles of major and minor keys (Krumhansl & Kessler, 1982) sufficient evidence? Does the strong tradition of Schenkerian thought in the music theory – the evident success of a theory based on prolongation of sonorities for subjectively accounting for the pitch structure of tonal music – count as convergent evidence in a social-sciences approach?

In Parncutt (2012), I found additional evidence for the psychological reality of the prolonged tonic triad in major-minor music in Huron's (2006) analysis of transition probabilities between scale steps in a large database of melodies in major keys. He found that of all possible transitions between scale steps, one and only one is consistently avoided: that between scale degrees 6 and 7, in both directions. This is what we might expect if melodies in major-minor tonality were prolongations of tonic triads: the triad 1-3-5 can be prolonged by a melody comprising the tones 7-1-2-3-4-5-6, all in the same octave register (with 7 being the lowest tone and 6 the highest). This idea does not prevent the transition 6-7 or 7-6, but it does make such transitions unlikely. The analysis was based on several thousand German folk songs; the sample is not necessarily typical of tonal music, but the finding is certainly suggestive and I know of no other explanation.

From a historical viewpoint, the familiar pitch patterns of modern major-minor tonality are the result of a long period of development. From a psychological viewpoint, that development can be described as follows. In the Renaissance, major and minor triads were prolonged due to their consonance (Salzer, 1952/1962). They were consonant because of their smoothness (they lacked 2nds) and harmonicity (they included perfect 5ths) (Parncutt, 1988). Triads were suitable psychological references because all diatonic scale steps lay within one step of a chord tone, enabling major and minor scales to emerge as prolongations of major and minor triads respectively (Parncutt, 2011). If passages of music in major and minor keys are indeed prolongations of their tonic triads, the emotional connotations of major and minor keys may be based on the emotional connotations of major and minor triads.

The evolutionary psychology of emotion

Emotions are what we experience when we are motivated to act in a way that will promote our survival or reproduction. For humans, that often involves the conscious pursuit of a goal. We know what we want, and we then try to get it, whether it be picking up something that we dropped, getting something to eat, having sex with someone to whom we are attracted, or rescuing a child from danger.

Because basic emotions are general phenomena that apply to diverse situations, they can be described as "domain-general". According to Nesse (2004, abstract),

> The situations that arise in goal pursuit contain adaptive challenges that have shaped domain–general positive and negative emotions that were partially differentiated by natural selection to cope with the more specific situations that arise in the pursuit of different kinds of goals.

Major and minor scales are similarly general in the sense of supporting an enormous variety of musical styles within Western "common practice".

Humans differ from other animals in their ability to reflect. Reflective consciousness gives us superior abilities to formulate goals and plan ways to achieve them. Positive emotions such as confidence are often associated with the achievement (or its reasonable expectation) of conscious goals; they are also associated with safety, which is a prerequisite for achieving goals. Negative emotions such as disappointment and anger are associated with failure to achieve conscious goals; they are also associated with danger, which is a threat to goal achievement. Negative, low-arousal emotions such as disappointment have the function of allowing or forcing us to reappraise our situation and not to act again until we have adapted our behavior to match the situation or found a new, more realistic strategy to deal with it. Negative, high arousal emotions such as anger give us the energy we need to respond to a new situation and fight to change it.

In his neuroevolutionary theory of emotion, Panksepp (2007, p. 146) identified seven core emotional systems:

> Four are substantially pre-mammalian, since they are evident in all vertebrates: FEAR, RAGE, SEEKING and LUST which are essential ingredients for feelings of anxiety, anger, desire and eroticism in mammals. With the expansion of mammalian limbic circuits ... there emerged robust CARE, PANIC

> and PLAY systems, which are fundamental brain substrates for the affective feelings of nurturance, separation distress/sadness, and social joy, respectively.

Of these seven, seeking (desire), lust (eroticism), care (nurturance), and play (social joy) are positive, and fear (anxiety), rage (anger), and panic (separation distress/sadness) are negative. Positive and negative valence are associated with different situations and meanings, making generalisations difficult. As a general rule, however, *clear, familiar*, or *safe* situations are often associated with positive emotions (such as confidence), while *unclear, unfamiliar*, or *unsafe* situations are associated with negative emotions.

The psychohistory of Western tonality

Much of human perception and behavior depends on exposure and learning, and much of what we are exposed to and interact with in our everyday lives depends on how society functions. That in turn depends on history, whose study involves additional academic disciplines such as sociology, politics and cultural studies. Thus, history co-determines both behavior and experience. It follows that psychological studies of any aspect of behavior and experience should not be confined to empirical studies of the present, but should also consider relevant aspects of history.

In the case of music, if we are to understand the origin of the emotional connotations of major and minor, we must consider the historical developments that led to the emergence of these connotations. The structure of tonal music depends on how musical structure developed in history. When did the association between major/minor keys and emotions became established, and why? Is it sufficient to claim that the association grew gradually over several centuries (say, the 14th to the 17th) at the same time as the musical structures themselves developed, that is, as the structural antecedents of major and minor keys gradually changed and became more rule-governed?

These questions belong to the broader question of the psychohistory of the major–minor system in Western culture (cf. Parncutt, 2001). My approach is inspired by the ancient pragmatic idea of Aristoxenus that musical intervals are pitch distances – not number ratios, as the more idealistic Pythagoreans believed. According to Aristoxenus, intervals vary in size on a continuous scale; semitones, for example, are perceived to be, and in real music performance really are, approximately half as wide as whole tones. While ontologies of musical intervals as number ratios dominated music-theoretical thought for two millennia, such conceptualizations may ultimately (with few exceptions) have had a negligible effect on the statistical properties of musical structures.The tonal musical language of Ludwig van Beethoven, Björk, or Antônio Carlos Jobim is surely based on the history, perception and reception of real music, and compositional intuition and trial and error – not Pythagorean thought. Musical preferences (e.g. preferences for certain contrapuntal patterns), although they were coded for thousands of years in terms of compositional rules that involve ratios, may ultimately be based on musical experience, which can today be described more realistically in the empirical approach of Aristoxenus and modern music psychology.

My psychohistory is divided into four main stages: the emergence of melody and scales in ancient music, the emergence of polyphony, the emergence of leading tones, and the emergence of major–minor tonality. Each of these historical developments was associated with a change in the way music was perceived and cognitively processed.

The first stage is the emergence of melody and scales. A melody is not merely a sequence of tones that go up and down in pitch; the pitches are also perceived and performed in categories that tend to correspond to notated pitches (Burns & Ward, 1978). A scale is a collection of pitch categories that reduce the information content of melody: it is easier to remember a limited number of scale steps than a series of exact pitches. Ancient diatonic scales presumably included intervals that are close to modern tones and semitones. These may have resulted from a general preference for perfect 8ve, 5th and 4th intervals between non-simultaneous tones, which in turn was due to tonal affinity or pitch commonality (Stoll & Parncutt, 1987). The ultimate origin of these intervals was presumably the harmonic series that is audible in every voiced speech sound.

The second stage of this brief psychohistory of tonality is the emergence of polyphony, which may be defined as a combination of voices that move independently of one another such that the intervals between them are constantly changing. The most important phenomenon requiring explanation in this case is the consonance and dissonance of harmonic intervals. From a psychological viewpoint, consonance and dissonance depend on roughness, harmonicity and familiarity (Parncutt & Hair, 2011). Assuming that consonances are consistently preferred in Western music, roughness and harmonicity can explain the usual rank order of prevalence of intervals in two-part polyphony (8ve, perfect 5ths and 4ths, major/minor 3rds and 6ths, and other intervals), which emerged in the history of music theory around the year 1100 (e.g. the organum treatise of Montpellier).

Durng the 13th to the 15th centuries, the harmonic perfect 4th (and sometimes the minor 6th) was often regarded as a dissonance. A modern explanation may involve pitch salience: usually, the lower tone of a harmonic interval is more salient, but the 4th (and to a lesser extent the minor 6th) is an exception. Familiarity with typical harmonic sonorities may also be a factor: in 3-part writing, the dissonance of the 4th is also associated with the dissonance of the suspended triad. In later tonal counterpoint, 8ves and 5ths were intuitively avoided because they encouraged perceptual fusion and reduce the audibility of individual voices (Huron, 1991).

The third stage is the emergence of leading tones in medieval polyphony. In general, leading tones lead from less stable to more stable pitches – usually by rising semitone (Bharucha, 1996). In Schenkerian terminology, a leading tone tonicizes the following tone, which is then more likely to be perceived as a tonic or as a stable goal of motion (e.g. the root of a prolonged chord, or a stable scale step). To tonicize means to increase tonal stability, but not necessarily to turn a tone into a tonic. One can distinguish two forms of tonicization, melodic and harmonic. Melodic tonicization increases the stability of a single tone, pitch or pitch class by movement through a semitone; harmonic tonicization may tonicize an entire triad, temporarily giving it the quality of a tonic or psychological reference (cf. Cadwaller & Gagné, 2010). According to Parncutt (2011), harmonic tonicization happens when the prevalence profile of pitch classes in a passage of music becomes closer to the pitch-salience profile of the triad that is being tonicized. Modulations or tonicizations in tonal music – the process by which musical keys are instantiated – often involve simultaneous melodic and harmonic tonicization.

Modern versions of early polyphonic scores often contain accidentals (that is, sharps, flats and naturals that apply to individual tones in the score – not key signatures) that correspond to what music theorists later called leading tones. These accidentals (usually sharps, sometimes naturals, rarely flats) are implied by the implicit rules of musica ficta (Berger, 2004). These rules differ from the implicit rules of voice-leading in major–minor tonality, but for the purpose of explaining the psychohistorical origin of leading tones, I will assume that the psychological function of leading tones is melodic tonicization in both cases.

To understand how leading tones work psychologically, it is necessary to consider both perception and history. What was the original function of leading tones, and how did

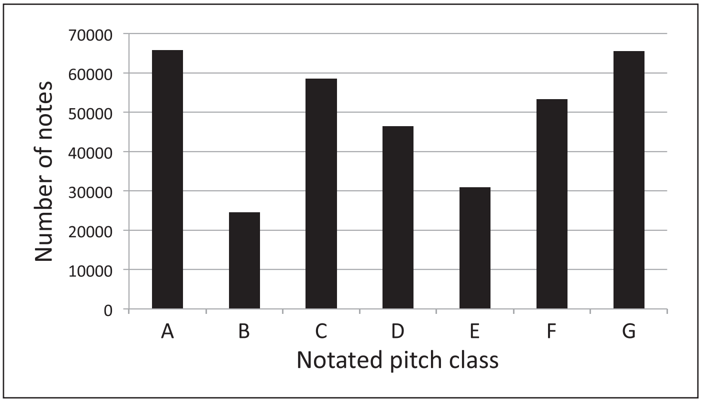

Figure 1. Number of notes in the entire *Liber Usualis* that correspond to each of the seven pitch classes in the white-note diatonic. Calculated using the DDMAL database (Thompson et al., 2011).

early listeners perceive them? Leading tones have two main music-structural features: they lie a semitone away from the tone that they tonicize, and they usually rise. The semitone interval is consistent with Wertheimer's Gestalt principle of proximity (Ellis, 1950), the trill threshold (quickly alternating pure tones sound like the same tone and not two different tones if the interval is less than about a quarter of a critical band: Shonle & Horan, 1976), and the general role of small intervals in promoting the perceptual coherence of melodies (Noorden, 1975) in the theory of auditory scene analysis (Bregman, 1990).

The dominance of rising over falling leading tones suggests that, for any two tones a semitone apart in a modal or tonal context, the higher tone is more stable than the lower. What is the historical origin of this relationship? A statistical analysis of a large electronic (Gregorian) chant collection (the *Liber Usualis* encoded in DDMAL; Thompson, Hankinson, & Fujinaga, 2011)[1] and an analysis of chants randomly selected from Bryden and Hughes (1969; Parncutt & Prem, 2008) has suggested that the feeling of leading from unstable to stable by rising semitone is already latent or nascent in chant. Independent analyses of these two data sets revealed that when chants are notated within the white-key diatonic scale and we count how often each scale step occurs in the chant – regardless of whether it is at the start, end or middle of the phrase, a tenor or final, and so on – the tone C happens more often than B, and F happens more often than E (see Figure 1). If the frequency of occurrence of a scale step is a measure of its stability as suggested by Krumhansl (1990), that implies that C is more stable than B and F is more stable than E. The language of medieval music theory allows us state this finding more concisely: relative to the hexachord *ut re mi fa sol la*, *fa* happens more often than *mi*, implying that *fa* is generally more stable than *mi*, no matter which scale degree the hexachord begins on.

This finding can be explained psychologically by considering the role of audible harmonics within single tones. A tone whose audible partials correspond well to its diatonic context is more likely to be perceived as consonant than a tone whose audible partials clash with its context. The former might therefore be intuitively preferred to the latter (Parncutt & Prem, 2008) – an example of pitch commonality (Parncutt, 1989). If we limit our considerations to the first 10 harmonics (since higher harmonics are rarely audible: Plomp & Mimpen, 1968) and consider only pitch classes, we can reduce the audible harmonics of a tone to 5 pcs: unison/8ve, 5th, major 3rd, minor 7th, and major 2nd/9th. If we further limit our considerations to diatonic tones, there is no need to consider the unison/8ve. The question becomes: How many

Table 1. Which harmonics of chromatic scale steps belong to the white-key diatonic?.

	C	C#/Db	D	D#/Eb	E	F	F#/Gb	G	G#/Ab	A	A#/Bb	B
Is the perfect 5th diatonic?	1	0	1	0	1	1	0	1	0	1	1	0
Major 3rd?	1	1	0	1	0	1	0	1	1	0	1	0
Minor 7th?	0	1	1	0	1	0	1	1	0	1	0	1
Major 2nd?	1	0	1	1	0	1	0	1	0	1	1	0
Number	3	2	3	2	2	3	1	4	1	3	3	1
Weighted sum	9	5	8	4	7	9	2	11	3	8	9	2

"Number" and "Weighted sum" are two different measures of the extent to which the harmonic series is represented within the diatonic scale above each pitch. The analysis is confined to pitch classes (octave register and enharmonic spelling are ignored) and harmonic numbers 1–10. The 1s and 0s within the table mean yes and no, respectively. Example: Above the tone C (2nd column), the harmonic series is represented in the C-major scale by G, E and D (Number = 3); B♭ is not part of the scale. The weighted sum is obtained by weighting each row of the table by the root-support weights of Parncutt (1993; see also 1997, 2009, 2011). The weight for the 5th is 5, for the major 3rd is 3, for the minor 7th is 2, and for the major 2nd (9th) is 1. The total weight for scale-step C is therefore 5 + 3 + 1 = 9. The table shows that the harmonic series is best represented above G, which can explain why G is the (equal-) most common tone in Gregorian chant. It is worst represented above F♯/G♭ and B, which can explain why B is the least common diatonic tone in Gregorian chant.

audible, harmonic, non-octave/unison pcs of a given tone are diatonic in a given context? For the note A, the answer is 3: the perfect 5th (the 3rd harmonic at E), the minor 7th (the 7th harmonic at G), and the major 2nd (the 9th harmonic at B); only the major 3rd (the 5th harmonic C♯) is not diatonic in this case. Following this logic, the number of audible, harmonic, non-8ve/unison harmonic pcs corresponding to audible partials above diatonic notes is 3 (for A), 1 (B), 3 (C), 3 (D), 2 (E), 3 (F) and 4 (G) (cf. Table 1). The correlation between this predictor and the data in Figure 1 is $r = .90$ ($df = 5$, $p < .01$).

Of course there are no leading tones in Gregorian chant, but the presented data suggest that movement from *mi* to *fa* in chant is the ultimate origin of the leading-tone effect in later music. The idea of counting the number of audible diatonic harmonics above a given tone can equally be applied to contrapuntal diatonic contexts: tones whose audible partials more often correspond to prevailing scale steps are likely to seem more consonant, and may be therefore be played or sung more often.

The fourth stage in this brief psychohistory of major–minor tonality in Western music is the emergence of the major–minor system, in which major and minor triads act as tonics and the diatonic scales with which they are associated are major and minor scales. The original basis for this system was the white-key diatonic scale (in arbitrary transposition), which – in different theoretical tunings, approached with different degrees of precision – has dominated Western music since antiquity. During the 15th and 16th centuries, the medieval modal system was gradually replaced in practice by the major-minor system. Terhardt's pitch theory offers a psychologically oriented explanation for this music-historical transition that is based on the perception of major and minor triads, which increasingly dominated music of the 15th and 16th centuries (although triads had barely been recognized as such by music theorists). Terhardt's theory predicts that the most salient missing fundamentals in typical voicings of a C-major triad are at pitch classes F and A, and in typical voicings of a C-minor triad, F and A♭. Adding leading tones to these sets almost completes the conventional major and minor scales. Scale degree 2 is co-determined by two constraints, one melodic and harmonic. The melodic constraint is the avoidance of consecutive semitones in musical scales (Pressing, 1978), a principle that can also explain why leading tones are avoided in Phrygian mode (if the interval between scale steps 7 and 1 is a semitone, the interval between 1 and 2 must be a whole tone – otherwise scale step 1 might be perceived as a chromatic passing tone, rather than a scale step in its own right). This principle already determined the structure of modes, and predated major-minor tonality by millennia. The harmonic principle emerged in the Renaissance, as music increasingly comprised progressions of simple root-position triads; triads were evidently preferred because of their special sonority (harmonicity from the perfect 5th above the bass; smoothness due to avoidance of 2nd intervals; Parncutt, 1988). Triads on structurally important scale degrees (which are near to the tonic on the cycle of 5ths) must have a perfect 5th above them; scale-degree 2 must lie a perfect 5th above scale degree 5 to enable the construction of dominant harmony.

According to this theory, the performers, composers and listeners of the 15th and 16th centuries gradually became more familiar with the sound of what were later referred to as major and minor triads, and hence with the pitches that they implied as missing fundamentals. As a result, they started to prefer contrapuntal contexts that conformed to what later became known as major and minor scales. Of course, the major–minor system involves more than scales; it also involves specific harmonic progressions and voice-leading conventions and paradigms (Renwick, 1995). Detailed consideration of such structures is beyond the present scope.

Competing theories of the emotional connotations of major and minor

Having considered some relevant general background, I turn now to theories that specifically predict the emotional connotations of major and minor triads and tonalities.

Dissonance: Are minor passages more dissonant, on average?

Nineteenth-century musical science produced two major psychological theories of consonance and dissonance in Western music. Von Helmholtz (1885/1954) explained the dissonance of harmonic sonorities by considering the intervals between harmonic partials of different tones and the perceptual roughness that they produced. Stumpf (1890) presented a contrasting theory in which sonorities are more consonant if they fuse in our perception, so that the number of tones that we hear is fewer than the actual number of tones.

The theory of Helmholtz is still generally accepted, although recent studies have shown that the effect of familiarity can override that of roughness (e.g. McLachlan, Marco, Light, & Wilson, 2013). Other studies have suggested that fusion as such may not be a foundation of consonance, but that harmonicity (the similarity of a spectrum with the harmonic series) is a more likely candidate (McDermott, Lehr, & Oxenham, 2010).

Von Helmholtz (1885/1954) suggested indirectly that dissonance might explain differences between major and minor keys. For him, dissonance depends not only on roughness and harmonicity, but also on combination tones: "The predominant minor chords have not the clearness and unobscured harmoniousness of the major chords, because they are accompanied by combinational tones which do not fit into the chord" (p. 301). But later empirical work by Plomp (1965) and Smoorenburg (1972) suggested that combination tones are rarely audible in music.

Does more dissonant music generally sound more emotionally negative? Is music in minor keys more dissonant, on average? That would be consistent with infants' preferences for consonance, as demonstrated by Trainor and Heinmiller (1998). The idea can hardly be refuted, but the size of the effect is unclear. The theory of Plomp and Levelt (1965) suggests that different voicings of major and minor triads differ considerably with respect to roughness – much more than the difference between the roughness of the average major triad and the average minor triad. Much the same can be said for harmonicity: the major triad indeed corresponds better to the harmonic series than the minor triad, but the psychological effect of this difference is unclear. When one considers a wide range of different sonorities, major and minor triads may be relatively close to each other in perceived harmonicity.

Von Helmholtz's theory predicts a positive correlation between the consonance of different chords and their emotional connotations, which seems intuitively correct. But there may be some interesting exceptions. For example, in the "soft rock" of artists like Burt Bacharach, Carole King, Carpenters, Eagles, Barbara Streisand and so on, harmonies often contain major and minor 2nd intervals that would render them dissonant according to Helmholtz; but they do not sound dissonant, nor to they evoke negative emotion. These chords are for example the major 7th chord, the minor 7th chord, and the diatonic eleventh chord (e.g. Dm7/G as a dominant in the key of C-major).

A further problem is that individual sonorities may not clearly imply either positive or negative valence. For example, an E-minor triad in a context of C-major tonality may have positive valence, because the valence of the chord is overridden by the valence of the tonality. Similarly, an A♭-major chord in a context of C-minor may have negative emotional valence. Thus, there is not necessarily a direct connection between the dissonance of a chord and the valence of a passage based on this chord. If, however, my adaptation of Schenker's theory of prolongation is correct, we might explain the emotional connotations of major and minor keys by combining Helmholtz and Schenker.

Alterity and markedness: Minor as the tonal Other, negative valence as the emotional Other

In anthropology, alterity is cultural otherness. When we perceive a person from a different culture, we do so from the biased perspective of our own culture. Categorizations based on concepts of race, ethnicity, class or gender can lead to misunderstandings and discrimination. If our culture is dominant, we are more likely to regard our biased perception as normal. It is not generally possible to free ourselves from cultural bias, because our identity is inseparable from our culture; however, cultural boundaries are generally fuzzy and cultural differences are fluid, so biases cannot always be clearly identified or explained. If we are aiming for an objective appraisal of people from other cultures, while at the same time acknowledging the impossibility of objectivity, or if we are merely striving to avoid or reduce discrimination, we must develop an understanding of alterity.

In linguistics, regular forms (such as regular verbs) are distinguished from "marked" forms that stand out in some way (such as irregular verbs). The relationship between an unmarked and a marked form is one of a primary, normal default form to a secondary, irregular exceptional form; it is one of dominance, breadth or ease to subordination, narrowness or effort (Battistella, 1990).

Alterity and markedness often involve power differences. For example, women traditionally have less political power than men in most societies. They are perceived and treated as Others unless corrective political mechanisms and institutions are in place. By analogy, in language female forms are grammatically marked; in English, for example, words such as "woman", "waitress" and actress" refer specifically to women, whereas "man", "waiter" and "actor" may refer to either men or women.

A power difference can also be produced by frequency of occurrence. The most common cultural group in a country often bears the country's name. In Austria, for example, "Austrians" (however defined) generally have more power than other people in Austria because they are the largest group and dominate traditional institutions. In language, males are referred to more often than females, just as Hollywood movies are more often about males, and more often presented from a male perspective; similarly, films that address "racial" issues more often present a "white" perspective (Willis, 1997).

In evolutionary psychology, the discrimination of Others is related to the tendency of individuals to divide other individuals into "goodies" and "baddies", the "baddies" often being free riders: people who do not return favors or selfishly overuse resources. Humans have a natural tendency to gang up on the baddies until they change their ways or are excluded, a process called altruistic punishment (Fehr & Gächter, 2002). If the cooperating humans are genetically unrelated strangers who will likely never meet again, this behavior can be explained in terms of its long-term social benefits.

Alterity may be defined simply as "The state of being other or different" (oxforddictionaries.com). Neither this definition nor the word itself refers explicitly to people. The concept may therefore be applied to the perception of any object, which will seem normal if it is perceived more often than other objects of the same kind or class, or has more in common with other objects. This is essentially the cognitive psychological theory of prototypes. Both acoustic and semantic prototypes play a role in infant language acquisition. Regarding acoustics, infants use statistical learning to segment speech into phonemes (Saffran, Aslin, & Newport, 1996) and develop phonemic prototypes that depend on frequency of occurrence (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). Regarding semantics, prototypes tend to have more in common with other examplars of a given category (family resemblances: Armstrong Gleitman, & Gleitman, 1983; Rosch & Mervis, 1975). In the statistical learning of tuning of musical intervals, intervals that are perceived more often tend to be perceived to be in tune (ideal, stereotypical) while deviations are out of tune (Burns & Ward, 1978). More generally, deviations from normality (objects of a given kind that are perceived relatively seldom) attract more attention: in visual images, vertical and horizontal lines are perceived as the norm, while tilted lines are exceptions to which observers partially habituate (Gibson & Radner, 1937).

Hatten (2004, p. 36) applied the linguistic idea of markedness to the minor key, to distinguish it from the more regular or normal major key:

> One kind of evidence for the stylistic encoding of a marked opposition is that the distribution of terms often reflects the asymmetry of their opposition—in other words, the marked term will occur less frequently than the unmarked. This is true for minor vs. major in the Classical style, but not in the early Baroque, where minor does not consistently invoke expressive states within the realm of the tragic. (p. 36)

It may seem far-fetched to apply terms like alterity or markedness to the minor mode, simply because it is less common than the major. Given that alterity and markedness also imply some form of prejudice based on category membership, we might expect something approaching discriminatory language when theorists try to explain the difference between the two modes. That is indeed what we find in von Helmholtz (1885/1954, p. 302):

> The major mode is well suited for all frames of mind which are completely formed and clearly understood, for strong resolve, and for soft and gentle or even for sorrowing feelings, when the sorrow has passed into the condition of dreamy and yielding regret. But it is quite unsuited for indistinct,

> obscure, unformed frames of mind, or for the expression of the dismal, the dreary, the enigmatic, the mysterious, the rude, and whatever offends against artistic beauty; - and it is precisely for these that we require the minor mode, with its veiled harmoniousness, its changeable scale, its ready modulation, and less intelligible basis of construction.

Given this general background, minor triads and tonalities may have negative valence simply because both happen less often than their major equivalents, so they are perceived deviations from the "normal" major "prototype". The minor triad happens less often because it is more dissonant or carries inherent negative emotional connotations. The minor triad may also be perceived as the Other triad because it has a weaker family resemblance with the harmonic series.

At another level, triads with perfect 5ths (whether major or minor) are perceived to be normal or unmarked relative to other sonorities. From the 13th to the 16th centuries, major and minor triads became increasingly prevalent by comparison to other vertical pitch-class sets (Parncutt, Kaiser, & Sapp, 2011). Even today, in spite of the complex development of pitch structures in Western music since the 19th century, if one randomly selects a radio station in a Western country, the sonorities that one hears will be mostly major and minor triads. Within triads, major has mostly dominated over minor. This predominance in mainstream European classical music (18th and 19th centuries) was demonstrated statistically by Eberlein (1994), who counted chords in a database of Western art music in major and minor keys. The music was composed in the period 1700–1850 by Bach, Händel, Mozart, Beethoven, and Mendelssohn. He found 513 major triads in root position, 200 in first inversion, and 69 in 2nd inversion. By comparison, he found 322 minor triads in root position, 157 in first inversion, and 83 in 2nd inversion. Of course chord prevalences differ from one style to another, but when the chord on the dominant is major in both major and minor tonalities, major sonorities are likely to dominate overall.

Similarly, major tonalities are generally more common than minor. In some styles, e.g. 19th-century European classical music ("romantic") or folk music from Russia, Turkey or Portugal, there seems to be a predominance of minor tonalities; but our perception may also be biased in a way that makes minor, the Other tonality, seem more intense and memorable. Even in these cases, major scales or passages of music may be perceived as the norm from which minor scales or passages of music deviate. These comments are limited to the Western major-minor system and do not apply to music that is not based on triads, such as Indian classical music.

If our attention is attracted more to minor rather than major tonality, it may be a a kind of *negativity bias*: a general psychological tendency to devote more attention to negative than positive events, objects, or qualities (Rozin & Royzman, 2001). In ancient environments, and perhaps still today, the negative implications of negative events (such as an attack by a predator) are generally greater in magnitude than positive implications of positive events (such as an abundance of food; Cacioppo & Berntson, 1994). Evolutionary theory therefore predics that negative stimuli will attract more attention. Baumeister et al. (2001, abstract) summarized diverse sources of evidence for a negativity bias as follows:

> The greater power of bad events over good ones is found in everyday events, major life events (e.g., trauma), close relationship outcomes, social network patterns, interpersonal interactions, and learning processes. Bad emotions, bad parents, and bad feedback have more impact than good ones, and bad information is processed more thoroughly than good. The self is more motivated to avoid bad self-definitions than to pursue good ones. Bad impressions and bad stereotypes are quicker to form and more resistant to disconfirmation than good ones. Various explanations such as diagnosticity and

> salience help explain some findings, but the greater power of bad events is still found when such variables are controlled. Hardly any exceptions (indicating greater power of good) can be found. Taken together, these findings suggest that bad is stronger than good, as a general principle across a broad range of psychological phenomena.

Negativity bias can explain, for example, why people in close relationships tend to overrate the importance of negative acts by their partners by comparison to positive acts; it is deemed sufficient to show gratitude for a good deed only once, whereas several apologies are needed to counteract a bad deed. There is also a *frequency bias*: infrequent experiences, whether positive or negative, are perceived to be more intense, and are more memorable (Winkielman, Knäuper, & Schwarz, 1998). These two biases interact: people tend to overestimate the emotional intensity and underestimate the frequency of recalled positive affect versus recalled negative affect, by comparison to real-time judgments (Thomas et al., 1990).

In the non-musical world of human emotion, positive valence (happiness, contentment, joy) is perceived as the norm whereas negative valence (anger, sadness, distress, grief) is the exception. The clearest evidence for this is simply the total duration of positive by comparison to negative emotional states. According to Diener, Sandvik, and Pavot (1991, pp. 130–131), whose research was carried out in the USA,

> When we turn from intense positive emotions to positive affect in general, a very different picture emerges; positive moods at less intense levels occur most of the time for the majority of our subjects. This fact squares nicely with the finding in all large-scale surveys that the majority of respondents claim to be happy. In a sample of 210 subjects, our respondents reported a preponderance of positive over negative affect on 75 per cent of their days. Only 8 per cent of the subjects were happy less than half of the time. [...] the distribution is highly skewed, with a plurality of subjects reporting a high percentage of happy days. At the same time, the average intensity of the happy days was only 3.2 on a zero to six scale, a response anchored by "moderate" in reference to how intensely the positive mood adjectives were being felt. Thus, it appears that our subjects experience weak levels of positive affect most of the time.

This is evidently the main effect, and it is largely unaffected by additional subsidiary effects. An example of a subsidiary effect is this: the frequency of negative emotions falls gradually as a function of age until about 60 after which the frequency stabilizes; highly positive emotional experiences last longer among older people than highly negative emotional experiences (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000).

Diener's finding is surprising to those who have the impression that negative experiences outweigh positive experiences. But such impressions may again be an example of negativity bias. Given this background, we may regard negative emotional states as strategies to get emotional states back to a normal state, which is tacitly understood to be positive. In the exceptional case that negative emotional states become normal, they are marked as "chronic".

It follows that, if certain conditions are fulfilled, there is a natural tendency for major triads and tonalities to be associated with normal emotion, namely positive, and for minor triads and tonalities to be associated with Other emotion, namely negative. These conditions are: music is generally perceived to be emotional, music is mainly triadic, major triads and tonalities are perceived as the norm from which minor triads and tonalities deviate, and positive valence is the norm from which negative valence deviates. Any accidental tendency in this direction, as historical performers and composers experiment with scales and tonalities, is likely to be reinforced.

Uncertainty and the variability of the minor scale

Von Helmholtz (1885/1954, p. 300) suggested that major tonalities are more common because they are simpler and clearer: "The major mode has, therefore, the character of possessing the most complete melodic and harmonic consistency, combined with the greatest simplicity and clearness in all its relations." That raises the question of whether a deep and consistent psychological connection exists between simplicity and clarity on the one hand and positive emotional valence on the other.

In an evolutionary approach, Nesse (2004) associated positive emotions with *opportunity* (for which a certain clarity or security may be considered a prerequisite) and negative emotions with *threat* (which is generally associated with uncertainty or insecurity). Anger gives us the motivation and the energy to resolve uncertainty by violent self-assertion; but we do not know in advance if our angry intervention will be successful. Similarly, "contentment occurs in circumstances appraised as safe and familiar" (Sander & Scherer, 2009, p. 100) – which, incidentally, may be the ultimate explanation for the positive correlation between liking a piece of music and its familiarity (Ritossa & Rickard, 2004). Such statements may apply equally well to humans and other animals from which we have evolved.

In standard Western music theory, the major scale has one form, but the minor has three: the harmonic minor with scale degrees ♭6 and ♯7, the rising melodic minor with ♯6 and ♯7, and the falling melodic or natural minor with ♭6 and ♭7. In conventional notation, only the natural minor requires no additional accidentals, since the ♭6 and ♭7 are included in the key signature. However, there is a strong tendency for triadic chord progressions in this scale to be perceived in the relative major key, whose tonic lies a minor 3rd higher. This ambiguity is reduced if the leading tone is sharpened, as in the harmonic minor scale. The augmented 2nd interval between ♭6 and ♯7 can be removed if scale degree 6 is sharpened. Thus, there are generally two positions for scale steps 6 and 7 in the minor key. Chromatic alterations also occur frequently in the major key, but such alterations may either be less common or less likely to induce a (passing) modulation (or cause tonal instability). Temperley (2007) found no difference in entropy between major and minor keys, but that does not change the basic music-theoretical observation that scale-degrees 6 and 7 have two normal positions in minor keys – a situation that has no parallel in major keys.

Meyer illustrated this point with musical examples:

> First, the minor mode is always potentially chromatic, and the listener practiced in the perception of and response to this music is well aware of the ever present possibility of chromaticism. Second, the tendencies of tones as they approach substantive tones is stronger in minor than in major. For the two most important substantive tones each have an additional "leading tone" in the minor: i.e., the fifth can be approached from a half step above and the tonic can be approached through the Phrygian second. … In other words, the minor mode is by its very nature more ambiguous than modes with a more limited repertory of tones. (Meyer, 1956, pp. 225–226).

By "ambiguous", Meyer meant that the tonic is ambiguous, which renders the function of all tones relative to the tonic ambiguous and produces a general feeling of uncertainty.

The variability of the minor scale can be explained by culture-specific, perceptually based principles for the construction of diatonic scales. One principle says that perfect 8ve, 5th and 4th intervals (perfect consonances) should be favored among the tones of the scale. So if the scale includes the tonic triad, then other tones within one octave of the scale should lie at 5th and 4th intervals away from tones in the tonic triad. Another principle says that scale tones should be roughly equally spaced, so that the scale covers pitch space roughly evenly. These two principles contradict: the first makes tones and semitones inevitable in 7-tone scales, so those scales are not equally spaced. However, asymmetrical scales have the advantage that they aid psychological position finding (Trehub, 1987). The second principle is partially satisfied by avoiding intervals of three semitones between adjacent tones (augmented 2nds); that is why the harmonic minor scale is often replaced in practice by the melodic minor scales. The harmonic minor may nevertheless prevail because it more clearly defines the tonic (the augmented 2nd interval aids position finding).

Said another way: the variability of the minor scale can be explained if we start with the minor tonic triad, add upper and lower 4ths to each tone, and then raise scale degree 7 to create a leading tone. That creates the harmonic minor scale, which includes an augmented 2nd interval. If that interval is considered undesirable because it contradicts the principle of evenly covering pitch space, it can be avoided either by raising scale degree 6 to create the rising melodic minor scale, or shifting scale degree 7 back down to create the falling melodic minor scale. No such problem and no such fundamental variability exists in the major mode.

When considering the psychoacoustics of pitch, we saw that the the root of the minor triad is more ambiguous than the root of the major triad. For different reasons, the minor scale is more variable than the major scale, and its tonic is more ambiguous. Since the major triad and the major scale are strongly associated with each other through the principle of prolongation (or simply by the co-occurrence of major tonic triads and major scales in music), and the minor triad and minor scale are similarly associated, minor-sounding contexts are generally more variable and ambiguous than major-sounding contexts, which in turn can explain the emotional difference.

Meyer's (1956) explanation for the negative valence and emotional power of the minor tonality is problematic in several ways. First, it was based on selected pieces and styles. Second, the scale-step ambiguity that he emphasized in the case of minor keys also occurs regularly in major keys. Third, chromaticisms of this kind may not suggest modulation at all, nor might they affect the music's positive valence. Conversely, music in minor keys that sticks to the harmonic minor scale is not necessarily more positive in valence than minor music in which scale degrees 6 and 7 are constantly being altered. Future statistical studies may clarify these uncertainties.

Speech: Emotion and pitch height in speech and music

Darwin (1872) suggested a functional relationship between expression in speech and music, an idea that was confirmed and elaborated by Juslin and Laukka (2003). Darwin's idea is plausible given the fundamental importance of speech for the acoustic communication of emotion by humans. The idea of a close relationship between emotion in speech and emotion in music is supported by neuroscientific studies. For example, the timing of ERPs (event-related brain potentials) as measured by EEG (Koelsch et al., 2004), suggests overlapping of corresponding brain regions.

Huron (2008) argued that slow music in minor keys is perceived to be sad or to have negative valence because its average pitch is lower and/or because intervals between successive melodic tones are smaller. Both effects are also present in sad speech. He also pointed out that these observations cannot explain the ultimate origin of the negative valence of minor keys.

If, however, we regard major triads and tonalities as the norm from which minor triads and tonalities deviate as Others, an interesting possibility emerges when we compare the way emotion is communicated in music and speech prosody. In the minor tonic triad, the 3rd is lower than expected relative to the "normal" major triad; and in the (harmonic) minor scale, scale degrees 3 and 6 are lower than expected relative to the "normal" major scale (Huron, Yim, & Chordia, 2010). This is an interesting candidate for an explanation of the emotional connotations of major and minor tonalities. We may simply perceive music in minor keys relative to music in major keys, which has a higher mean pitch and larger intervals. Another way of saying this is that the average pitch and the average interval size of music in minor tonalities is lower than expected, when we are expecting major tonalities. The argument is particularly convincing if we assume that a melody is like a person that speaks to us – a musical persona (Watt & Ash, 1998).

More generally, according to Temperley and Tan (2013), church modes sound happier for two reasons: if they are more familiar (Ionian sounds like major, Aeolian like minor), and if they have more raised scale degrees (Lydian has the most). They sound sadder if they are less familiar and have more lowered scale degrees, so Phyrgian is saddest – at least when the tonic is held constant. Temperley's explanation based on the line of 5ths is problematic, because evidence for the psychological reality of the line of 5ths is unclear. By contrast, there is no doubt about the psychological reality of the pitch of individual tones, or the pitch of sad speech. For this reason, I prefer a theory based on pitches or scale steps that are simply lower than expected.

Is it possible for an untrained listener to perceive the 3rd of a minor triad as being lower in pitch than the 3rd of an expected major triad on the same root? Several sources of evidence suggest that the answer may sometimes be yes. The ear is remarkably sensitive to very small differences between expected and heard sounds, as the success of physical models of musical timbre by comparison to sophisticated spectrotemporal synthesis suggests (Välimäki & Takala, 1996). Even non-musician listeners, including infants, are sensitive to small pitch changes (Trainor & Trehub, 1992). In most tonal music, both major and minor triads consistently occur more often in root position than in version (Eberlein, 1994); this regularity might help the listener to compare the structure of major and minor triads relative to the root and to notice that the 3rd is lower in the minor case.

An argument against this theory is that pitch height in music is normally associated with arousal, not valence: music with a high average pitch seems to have more energy than music with a low average pitch. High-register pieces in minor keys are not generally happy, nor are low-register pieces in major keys generally sad. The theory can work in spite of this apparent contradiction if we assume that listeners respond differently to small and large pitch changes. Small changes in pitch may be perceived as deviations from expected pitches or chroma, whereas large changes may be perceived as registral or timbral changes.

Another argument against this theory is that there is more to negative salience than sadness. Angry speech is higher than normal, not lower. The theory may therefore be confined to sadness, and cannot be generalized to all negative emotions. The superior ability of minor tonality to express anger may instead be due to its relative dissonance or tonal uncertainty.

Salience: The instability of leading tones and sharps

A database analysis by Craig Sapp using David Huron's Humdrum toolkit, presented in Parncutt and Sapp (2011), provided evidence that sharps are generally and consistently more common than flats in tonal music. In a database of folk melodies (Deutscher Liederschatz 1859–1872, Band 1, collected by Ludwig Erk), 200 songs were investigated with altogether 1,590 marked accidentals. Of these, 196 songs were in major keys with 1,475 accidentals, that's 7.5 accidentals per song; 4 songs were in minor keys with 115 accidentals, that's 29 accidentals per song. The difference between major and minor is evidently because the leading tone is generally sharpened in minor, and the sharp (or natural) is separately notated. Of all the accidentals in these 200 songs, 1,131 were sharps and 459 were flats; in the 4 minor songs, 115 notes were sharps and none were flats. Sapp also investigated 370 4-voice Bach chorales, of which 185 were in major keys, 139 in minor keys, and the rest were judged to be modal by Burns (1995). The 185 chorals in major keys contained 42,571 notes, of which 1,534 were sharps and 465 were flats relative to the key signature. The 139 chorales in minor keys contained 30,847 notes, of which 2,628 were sharps and 208 were flats relative to the key signature. Thirty-seven Chorales were Dorian, with 656 sharps and 608 flats; and 9 were Mixolydian with 110 sharps and 18 flats. If Bach chorales are tonally typical or normative, as many teachers of harmony and counterpoint assume, it is clear that sharps are generally more common than flats in both major and minor keys.

A possible general reason why sharps are more salient than flats is that flats are generally more salient, and therefore are more likely to disturb the prevailing tonality or invoke a passing modulation. That may in turn be because flats are more likely to be fundamentals of incomplete harmonic series of audible partials (Parncutt & Sapp, 2011). If that is true, it has profound music-theoretic implications.

Table 1 considers the most common chromatic alterations relative to the white-key diatonic. The most common flat in (modern scores of) medieval music, and in the key of C-major or A-minor in "common-practice music", is B♭ (seldom notated as A♯). Table 1 shows that the harmonic series is well represented above this pitch within the diatonic scale. The most common sharp in the key of C-major is F♯ (seldom notated as G♭); the harmonic series is poorly represented above it. The most common sharp in A-minor is G♯ (seldom notated A♭); again, the harmonic series is poorly represented above it. Table 1 also includes predictions ("number", "weighted sum") for the frequency of occurrence of diatonic scale steps in chant, on the assumption that tones are preferred whose audible partials better fit the prevailing diatonic scale. These predictions can explain why *fa* is generally more common than *mi* (C more common than B, and F more common than E).

The claim that sharps generally outnumber flats, making flats another kind of marked Other, is also supported by a statistical analysis of Bach chorales (Craig Sapp, personal communication). If all 185 chorales in major keys are transposed into C-major and the accidentals are counted, we find 325 cases of C♯, 2 of D♭, 38 of D♯, 34 of E♭, 843 of F♯, 0 of G♭, 328 of G♯, 10 of A♭, 0 of A♯, and 419 of B♭ (altogether: 1,534 sharps and 465 flats). If the usage of accidentals in Bach chorales is representative of other music major and minor keys, we may conclude that C♯, F♯, G♯ and B♭ are the predominant accidentals in major keys. Similarly, when 139 chorales in minor keys are transposed into A-minor, we find 416 examples of C♯, 0 of D♭, 190 D♯, 15 E♭, 789 F♯, 0 G♭, 1,226 G♯, 5 A♭, 7 A♯, 188 B♭ (altogether: 2,628 sharps and 208 flats). The predominant accidentals in A-minor are thus C♯, D♯, F♯, G♯ and B♭. The only flat that occurs consistently more often than its enharmonically equivalent sharp in C-major or A-minor is B♭.

Are sharps more common than flats because flats are more perceptually salient, so they are more likely to upset the prevailing tonality? To test this idea, Parncutt and Sapp (2011) presented diatonic progressions of five chords to musicians and non-musicians. All chords were major or minor triads of octave-complex tones. The first was the tonic; the others were ii, IV, V and vi in major keys and ii, IV, v and VI in minor. The last four chords were presented in all 24 different orders. In half of all trials, the penultimate chord was changed from major to minor or vice-versa. All listeners heard all trials in a unique random order and rated each progression's unusualness. Musicians were separately asked whether the last chord contained an accidental relative to the key signature. Results showed that both progressions in minor keys and progressions with an accidental in the final chord sounded more unusual, and musicians were more likely to report that they contained an accidental. Flats sounded more unusual for both musician and non-musician listeners, consistent with three possible explanations: flats are less familiar (because they are less common), flats are more perceptually salient, or minor triads sound more unusual. The last point can in turn be explained in three ways: minor triads happen less often in real music, minor triads are less consonant, or the 3rd of a minor triad is more salient than the 3rd of a major triad. These results are consistent with the idea of minor as the tonal Other, but they are insufficient to demonstrate higher salience for flats because of the difficulty of separating factors in the experiment. More convincing evidence for this asymmetry is found in psychological studies on the asymmetry of the circle of 5ths: modulations to flat-side keys are perceived to be more distant than modulations to sharp-side keys on the circle of 5ths (Cuddy & Thompson, 1992; Thompson & Cuddy, 1989).

If flats indeed attract our attention more, and disturb prevailing tonality more than sharps, that might explain Meyer's (1956) suggestion that chromaticisms in minor keys sound more emotionally intense because "the tendencies of tones as they approach substantive tones is stronger" (p. 225). But in a minor key, *diatonic* scale degrees 3 and 6 may be more likely to undermine the tonic and induce a feeling of instability or modulation than in major; in the natural minor scale, 3 and 6 may be more perceptually salient because both the major 3rd (5th harmonic) and the perfect 5th (3rd harmonic) above them correspond to diatonic scale steps (whereas for scale steps 3 and 6 in a major key only the perfect 5th or 3rd harmonic is diatonic). If the leading tone in a minor key is consistently sharpened to produce the harmonic minor scale, only scale degree 6 in minor is reinforced in this way. In general, the increased salience of flats makes the tonic more ambiguous, which produces uncertainty and hence negative emotion. In this way, a combination of different theories might explain the emotional effect.

Before closing this section, I should bring together some threads. I have explained two different phenomena in tonal music on the basis of the same theoretical idea from non-musical pitch perception: we tend to hear pitches at missing fundamentals of incomplete harmonic series. In the first case, I suggested that a major or minor scale can be created by starting with the tones of the tonic triad and then adding missing fundamentals (e.g. by adding F and A to a C-major triad). This idea can explain why the tones F and A are relatively *common* in C-major key contexts. In the second case, I argued that flats are more salient than sharps in diatonic contexts, which explains their *rarity*: they disturb the prevailing tonality. This apparent contradiction can be resolved by the concept of optimal psychological complexity as a foundation for aesthetic preferences (Heyduk, 1975; North & Hargreaves, 1995). In the first case, a chord is not complex enough to make music; according to basic principles of auditory scene analysis and melodic streaming, stepwise motion is necessary to make psychologically coherent melodies (Huron, 2001). There are not enough tones in a triad to make a melody; the theory explains, in part, which extra tones are chosen for music in major and minor keys. In the second case, we already have a diatonic scale, which provides enough tones to make coherent melodies. Extra tones increase complexity, perhaps beyond the psychologically optimum level; we therefore tend to favor tones that have lower pitch salience and minimize disturbance to the prevailing tonality (sharps rather than flats).

Familiarity: Recognition of arbitrary emotional associations

Cazden (1972) proposed that the perception of consonance and dissonance in music is primarily learned from music and does not depend on number ratios:

> Thus music springs neither out of some immanent property of the tones themselves, nor out of an automatic delight in the forming of any and all possible patterns out of tones, guided by no previous

> experience. Musical relations are instead given in the set of habits that have evolved in a given music culture and that are accordingly transmitted as crystallizations of that culture's history. It is through his (*sic*) social inheritance, and not merely through his auditory and perceptual sensitivities, that the individual grasps and also re-formulates the conceptual structure and meaning of music. The human auditor or musician does more than merely perceive the pitches and pitch intervals that enter into harmony: he also judges them, and where need be he transforms them, in the larger frame of a priori culture-bound, because culture-variable, system of music-making to which that individual has been conditioned. (p. 219)

Many aspects of musical meaning can be explained in this way. The origin of the emotional connotations of major and minor tonalities is one example. Another related example is the allegedly different character of musical keys. Powell and Dibben (2005) observed that musicians who believe in associations between musical keys and moods (e.g. sharp keys as bright and positive, flat keys as dark and negative) are generally unable to perceive these effects themselves, suggesting that key character (called *Tonartencharakteristik* by Schubart, 1806) is the product of an arbitrary cultural development (the diatonic basis of standard music notation, and subsequent need for sharps and flats). The emotional connotations of major and minor can be explained similarly: the association of major with positive valence and minor with negative may have arisen accidentally and been reinforced by familiarity. Thus F major may be considered "pastoral" because of well-known pieces in that key, which reinforces the more general association of positive emotion with major keys. But we cannot do the experiment of trying to create a culture in which major has negative valence and minor positive. The arguments presented in this article suggest that such an experiment is both practically and theoretically impossible: while it is true that familiarity and associations play an important role, so do other factors.

Conclusion

The following theories compete for an explanation of the emotional connotations of major versus minor tonalities in Western music.

Cultural learning

The emotional differences between major and minor tonalities emerged by accident during the 14th to 16th centuries as the tonal system itself was emerging. Small differences were reinforced as composers progressively developed their emotional vocabulary.

Dissonance

On average, sonorities in minor-key passages are more dissonant because they evoke more acoustic roughness, have lower harmonicity (their spectral are less similar to the harmonic series), or both.

Uncertainty

Uncertainty is associated with insecurity and negative emotions.The minor scale has three theoretical forms, because there are two possible positions for the 6th and 7th scale degrees. No such theoretical ambiguity exists in the major scale.

Alterity

Minor tonalities are less common than major, and negative emotions are less common than positive. In both cases, the more common phenomenon may be perceived as the norm and the less common as the Other. If music is generally emotional, these two Others may spontaneously become associated.

Speech pitch

Assuming that minor is perceived as the Other tonality, scale degrees 3 and 6 in minor are lower than the norm (which is major), just as the pitch of sad speech is lower than the norm (happy speech).

Perceptual salience of flats versus sharps

If flats are generally more salient than sharps (because the harmonic series above them is better represented in the local musical context), flats are generally more salient and more likely to upset the prevailing tonality. For this reason, diatonic scale degree 6 and (to a lesser extent) 3 are more destabilizing in minor than in major keys.

Pitch/root ambiguity and prolongation

The minor triad has a more ambiguous root than the major. If a passage of music in a major or minor key is perceived as a prolongation of its tonic triad, that can explain why, in minor tonalities, the tonic is more ambiguous and modulations are more frequent.

Considering this list, it is not immediately clear which theory should be privileged by comparison to the others. There are arguments for and against each theory. Perhaps the truth lies between the theories, or in a mixture of them. One might for example argue as follows: By comparison to the major scale, the minor is both more variable (ambiguous, unclear) and less common (less "normal"). That is in part because of the ambiguity of the minor tonic triad, which may in turn be explained by theories of pitch perception, and in part because of the way major and minor scales are constructed starting from their tonic triads, favoring perfect intervals, and incorporating leading tones. Passages of tonal music may be perceived as prolongations of their tonic triads, the minor triad having a more ambiguous root. Scale degrees 3 and 6 are lower than expected in minor keys (the Other tonality) by comparison to major, just as sad speech is lower than expected (the Other emotion). These lower scale degrees are also more perceptually salient, because the harmonic series is better represented above them in the local context; that contributes to the ambiguity of the minor mode.

An inherent problem that occurs repeatedly in such theorizing is the existence of just two data points to explain: major and minor. A theory is generally more convincing if it can account for many more than two points – in this case, a range of different chords and scales/modes. The theories I have presented can generally be expanded to fulfill this criterion, although sometimes corresponding empirical data are lacking (Temperley & Tan, 2013, provided such data). For example, atonal music (such as that of Schoenberg) would appear generally to have negative valence. That is consistent with the assumed relationship between emotion and scalar variability, but it would also be interesting to test the emotional valence of a range of different styles with controlled degrees of scalar variability.

Most research papers in modern music psychology are empirical – both in general and on this particular topic. In this article, I have tried to redress the balance by working mainly theoretically, bringing together existing sources of evidence from various sources, and constructing a new argument. I hope to inspire future empirical studies to close remaining knowledge gaps. If one or more of the presented theories is incorrect or relatively unimportant, and should therefore be eliminated from the list of promising theories, that will presumably happen on the basis of new empirical evidence. Similarly, if one of the theories is found to be the most promising and then becomes widely accepted, new empirical evidence will again be the likely trigger. Given the culture-specific use of chord progressions in Western music, I doubt that critical evidence of this kind will be found by studying non-Western musical cultures. Instead, new empirical data on issues such as the variability of the minor scale or the psychological reality of the prolongation of the tonic triad could be useful.

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Note

1. DDMAL did not offer the trivial option of counting how often individual pitch classes occurred. I therefore constructed a table for the frequency of occurrence of successive 2-tone transitions relative to the seven diatonic pitch classes. In the process, accidentals were ignored. To check whether instances of B♭ might have affected the results, I counted occurrences of the intervals B-F and F-B, in which the B must be B♭. In the entire database, I found only 163 instances of F-B and 155 of B-F. Since the database contains about 24,600 Bs, less than 1% of them are B♭s.

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