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## **Are scale degree qualia a consequence of statistical learning?**

**David Huron**

School of Music, Ohio State University  
Columbus, Ohio, U.S.A.

### **ABSTRACT**

*Ten musicians were asked to describe the quality or character evoked by different scale tones in the Western major scale. For example, the “mediant” pitch was variously described by participants as light, lifted, restful, peaceful, warm, bright, or calm. An informal semantic analysis of the descriptive terms resulted in seven categories, including the categories of surprise, tendency and completion. Independently, statistical data were collected on the probability of different scale tones in a large sample of Western melodies in major keys. There appears to be a notable association between the subjective qualia reported by musicians and the basic statistical properties of scale tones for Western melodies. Scale tones described by musicians as surprising or unexpected have objectively lower zeroth-order probabilities of occurrence. Scale tones characterized as tending, leading, or pointing, are more likely to be those tones that are objectively most highly constrained in their first-order melodic probabilities. Scale tones de-*

*scribed as stable or restful, are more likely to be those tones that exhibit a high probability of terminating a phrase or work. Most of the qualia categories, including certainty, tendency, completion, mobility and stability appear to be readily interpreted as relating to the statistical properties of tones and tone successions. These informal observations are consistent with the idea that the subjective experiential qualia evoked by tones may be attributable to statistical learning.*

### **Keywords**

music, emotion, statistical learning, scale degree, qualia.

### **INTRODUCTION**

Emotion-related research has traditionally focused on “strong” emotions such as anger, fear, joy, and sadness (e.g., LeDoux, 1996; Scherer & Oshinsky, 1977). This emphasis on strong emotions is also found in studies of musically-related emotions, which have tended to focus on such experiences as frisson (“shivers”), joy, and grief (e.g., Gabrielsson, 2001; Gabrielsson & Lindstrom, 1993; Juslin, 2000; Panksepp, 1995; Scherer & Zentner, 2001; Scherer, Zentner & Schacht, 2001; Sloboda, 1991, 1992). There are good reasons why researchers might focus on strong emotions. Strong emotions are more likely to be accompanied by large metabolic changes or gross motor behaviors that are relatively easy to observe or measure. In addition, participants are more confident when introspecting and reporting changes of affective state when major emotions are experienced. Subtle shifts of emotion are both more difficult to detect and less accessible to introspection.

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Strong emotions are musically important. Intense emotions are more memorable and more meaningful to listeners. However, such “affective fireworks” are relatively rare when listening to music. Moreover, music continues to be experienced as pleasurable, even when strong emotions are absent. Ben-Ze’ev (2000) has noted that the majority of emotional experiences are more subdued and subtle. When listening to music, listeners commonly experience a sequence of muted feelings. These less powerful experiences might be referred to as “micro-emotions.”

At least two classes of feeling states can be distinguished: *valenced* and *unvalenced*. Strong emotions (and many weaker emotions) are typically *valenced*—that is, they evoke positive or negative phenomenal experiences that are regarded as motivational amplifiers (Tomkins, 1980). Other feelings appear to be unrelated to motivation and so are not easily characterized as either negative or positive. These latter feelings may nevertheless evoke a highly distinctive affective state or *qualia*.

The term *qualia* was popularized by Clarence Lewis (1929). It refers to the distinctive subjective feelings that accompany sensory experiences. When touching a glass object, for example, one might experience a unique sensation of smoothness and coolness. The feelings are ineffable and private, and so not easily communicated in words.

*Qualia* accompany all consciously experienced sensations, including the sensation of sounds. Different sounds may evoke various *qualia*, such as the “quiet raspiness” of an elderly person’s voice, the “delicate innocence” of a recorder tone, or the “noble roundness” of a trombone sound.

One of the most common sources of music-related *qualia* can be found in the distinctive feelings evoked by various scale degrees. For most Western-enculturated listeners, the different scale tones project unique feelings or qualities. An isolated *tonic* pitch, for example, may evoke a sense of stability, repose or completeness. When hearing the *leading tone*, by contrast, listeners often experience a sense of precariousness or instability mixed with some urgency and accompanied by feelings of yearning or aspiring upward. That is, the tonic and leading-tone pitches evoke strikingly different *qualia*. Where do these distinctive feelings come from?

## QUALIA SURVEY

In approaching this subject, two preliminary questions

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arise: Do scale tones evoke stable and consistent subjective

feelings? And are these feelings shared across Western-enculturated listeners? In order to address these questions a survey was carried out. In brief, musician participants were asked to provide written descriptors for each scale tone. In order to limit the scope of the study, the survey was restricted to the major scale only.

## Participants

Participants were 10 volunteer musicians drawn from the Ohio State University School of Music. Subjects included 4 graduate students, 5 faculty members, and 1 post-doctoral fellow. The participants ranged from 24 to 58 years of age. All were experienced musicians.

## Instructions

Participants received a single-page survey identifying 13 scale degree categories (see Table 1). Each musician received the following instruction:

For each of the following scale degrees describe as best you can the distinctive quality or character of that tone. Describe how the tone makes you feel in as much detail as possible. Imagine the tones for the major key only. Please think of pitches rather than chords. Aim to provide a minimum of 10 adjectives or descriptive words for each scale tone.

In total, the 10 participants provided just over 600 words over the 13 pitch categories. Each of the twelve chromatic tones was included in the survey. In addition, a single enharmonic distinction was made between the raised tonic and the lowered supertonic pitches. This allowed participants to potentially generate diverging *qualia* descriptions for enharmonically equivalent pitches. No other enharmonic equivalents were included in the survey.

Although participants were encouraged to come up with 10 adjectives or descriptive words for each scale degree, participants generated an average of only 4.7 words for each scale tone. In post-survey interviews, participants claimed that the task was not difficult, but that it was challenging to come up with 10 descriptors for each scale tone.

Note that this task assumes that isolated tones are able to evoke *qualia* independent of some musical context. It also assumes that musicians can introspect about such matters without actually hearing the sounds, and it assumes that language can be used to express the ineffable qualities people experience.

## Results

A summary of the survey results is given in Table 1. The first column identifies the scale degree: *tonic*, *supertonic*, and so on. The second column identifies the most frequent words and themes given in the participants’ descriptions. Some sample responses from the participants are provided in the third column.

When using qualitative data, it is difficult to formally characterize the level of agreement between subjects. A simple approach might tally the occurrence of identical descriptive terms in each scale degree category. For example, seven of the ten participants used the word “unstable” in describing the leading tone. Six of the ten participants used the word “bright” in describing the mediant pitch. All of the participants associated the tonic with pleasure, satisfaction, or contentment.

There were also a number of discrepancies evident. For example, one participant described the subtonic (lowered leading tone) as “light” whereas a second participant described this same pitch as “heavy.” The dominant pitch was described as both “stable” and “unstable.” However, overall, such discrepancies were the exception: viewed informally, the descriptions showed a relatively high level of agreement.

In order to test the adequacy of the *qualia* descriptions, two nonmusicians were recruited for a simple test. A key-defining context was played on the piano, followed by a particular scale tone. Test participants were asked to choose which of three aggregate *qualia* descriptions best matched the scale tone they heard. One of the descriptions was the actual description for the particular tone. Two other lures were randomly selected from the remaining *qualia* descriptions shown in columns 2 and 3 of Table 1. Since no other musical context was provided, the enharmonically-distinguished raised tonic and lowered supertonic were omitted from this test. Consequently, the non-musician listeners judged only 11 scale tones, and saw only 11 *qualia* descriptions. A random performance would result in 1/3 correct choices. However, the two nonmusician participants scored 6/11 and 7/11 correct. *Prima facie*, the results are consistent with the view that listeners experience broadly similar *qualia* when hearing particular scale tones in a major key context.

**Table 1. Sample *qualia* survey results**

Scale Tone	Common Descriptors	Sample Responses
tonic	stable, pleasure, home, contentment	stable, extremely satisfying, centered, foundational, solid, resolved, strong
raised tonic	strong, upward, bold	edgy, unstable, uncertain, upwardly mobile, mildly precarious
lowered supertonic	surprise, abruptness, pause	somewhat dark, a sense of almost inevitable further descent, murky, unexpected richness, mild surprise
supertonic	solid, movement, resolve	hanging, dangling, transitory, moderate expectancy of more to come, part of a flow
mediant	bright, love, warmth, beauty	light, lifted, point of many possible departures, yet also strongly restful, peaceful and calm
subdominant	descending	awkward, tentative, strong sense of being unfinished, “Now what?” no clear expectation of future, hanging feeling, would be happy to fall by half-step
raised subdominant	intentional, motivated	moderately anxious, interrupted flow to dominant, somewhat curious about possibilities, fluidity, transitory
dominant	strong, muscular, balance, possibility, pleasant	strong, towering, height, sense of looking down from a tall building & being comfortable, but knowing you’ll eventually take the elevator back to the street level
raised dominant	balance, open, lightness	leading to something, sense of implication, unfinished, leaning, mildly uncomfortable
submediant	balance, open, lightness	airy and open, temporary suspendedness, neutral, evokes mild curiosity in regards to direction
subtonic	falling, lightness, drifting downward, shifting	heavy, like walking with a limp, unexpected, open new possibilities, sheds a new light on things
leading tone	unstable, pointing, restless	sense of inevitability, highly unstable, uncomfortable, squirrely, itching, restless

### Semantic Analysis of *Qualia* Descriptions

Working from a complete list of words used in the musicians’ descriptions, similar terms were informally clustered together, including synonyms and antonyms. The survey respondents used a large number of metaphors to describe

their feelings, including lightness/darkness, open/closed, rising/falling, irritation/comfort, and so on. However, seven semantic categories seem to account for most of the descriptions. The seven categories include (1) certainty/uncertainty, (2) tendency, (3) completion, (4) mobility, (5) stability, (6) power, and (7) emotion.

The first proposed semantic category pertains to certainty/uncertainty. In the sample of scale-degree descriptions, obvious certainty/uncertainty words included “inevitable,” “unexpected,” “surprise,” “abrupt,” “many possible departures,” and “now what?”

A second semantic category has to do with sequential tendency. For example, most of the participants described the raised tonic as “upward tending.” Sample descriptive terms included “tending,” “leaning,” “pointing,” “upward,” and “downward.” Other words that might be included in this category are “longing,” “motivated,” “falling,” and “intention.”

A third category might be dubbed completion. Sample words included “unfinished,” “hanging,” “dangling,” and “transitory,” as well as “resolved,” “home,” “finished,” and “complete.”

A fourth category appears to relate to mobility. Sample words included “movement,” “repose,” “flow,” “fluidity,” and “drifting.”

A fifth category relates to stability. For example, eight of the ten participants described the tonic pitch as “stable.” Other stability/instability words included “balance,” “precarious,” “solid,” “foundational,” “squirmy,” “restless,” “transitory,” and “unstable.”

A sixth category relates to power. Power words included “muscular,” “heavy,” “towering,” “energized,” “bold,” “light,” and “delicate.”

A final category appears to relate to emotional valence – that is, words indicating positive or negative feelings. Emotion-related words included “pleasure,” “love,” “calm,” “satisfying,” “contentment,” and “beauty.” Negative assessments are evident in words such as “edgy,” “anxious,” “harsh,” “jarring,” “itching,” and “uncomfortable.”

Given a particular key context, a simple pitched tone seems to be capable of evoking a cornucopia of psychological impressions or feelings for Western-enculturated listeners. So where do these feelings come from?

**STATISTICS OF SCALE DEGREES**

Recent auditory research has drawn attention to the importance of statistical learning. Listeners are known to be sen-

sitive to the frequency of occurrence of sounds. Krumhansl (1990) has suggested that the distributions of major and minor scale tones are internalized by listeners through exposure. Saffran et al. (1999) has provided explicit experimental evidence consistent with statistical learning of pitch patterns through simple exposure. Desain, Honing and Sadakata (2003a/b) have similarly shown that the perception of rhythmic patterns is consistent with statistical learning by exposure. Huron (2006) has reviewed much of the empirical evidence in support of statistical learning in the case of music. Can simple statistical learning somehow account for the *qualia* evoked by different scale degrees? Can we account for the feelings listeners experience by understanding the statistical patterns evident in the music itself?

In order to address this question, statistical data were collected on the probabilities of different scale tones in a large sample of Western melodies in the major key. Collected data included the zeroth-order probabilities of individual scale tones as well as the first-order probabilities for different tone successions (see Table 2).

**Tending**

Consider first, the *qualia* of *tending*. Some scale degrees (such as the raised subdominant) are highly constrained so that there are only one or two likely continuation tones. By contrast, other scale degrees (such as the dominant) have very few constraints on possible ensuing pitches. In 2001, Bret Aarden calculated the first-order statistical tendency for scale degrees using information theoretic measures. From Aarden’s analysis of melodic intervals in major keys, the order of scale tones from least to most constrained is as follows: dominant, tonic, supertonic, mediant, subtonic, subdominant, leading tone, submediant, lowered mediant, lowered submediant, raised subdominant, and raised dominant. (The raised-tonic/lowered-supertonic did not appear in Aarden’s sample.) Given the qualitative descriptions provided by the scale-degree survey participants, it is difficult to calculate the degree of *tending* implied for each scale degree. However, the descriptions that most imply tendency appear to be those for the subdominant, leading tone, submediant, and raised dominant. That is, those scale-degrees that musicians judge as exhibiting the most “tending” *qualia* appear to be those tones whose pitch continuations are most statistically constrained.

**Table 2. First-order scale-degree probabilities (diatonic continuations only)**

Antecedent	Consequent							
	1	2	3	4	5	6	7	rest

<b>1</b>	0.03416	0.02806	0.01974	0.00210	0.01321	0.00839	0.02321	0.03678
<b>#1</b>	0	0.00042	0.00004	0	0	0.00003	0.00002	0.00002
<b>b2</b>	0.00004	0	0.00001	0	0	0	0	0
<b>2</b>	0.04190	0.02632	0.03282	0.00678	0.00825	0.00201	0.00586	0.01521
<b>#2</b>	0	0.00000	0.00018	0	0	0	0	0.00000
<b>b3</b>	0.00030	0.00108	0.00001	0.00071	0.00010	0	0	0.00017
<b>3</b>	0.01555	0.04865	0.03142	0.02644	0.02365	0.00281	0.00029	0.02357
<b>#3</b>	0	0	0.00000	0	0	0	0	0
<b>4</b>	0.00054	0.01260	0.04127	0.01506	0.01712	0.00441	0.00125	0.00537
<b>#4</b>	0.00003	0.00016	0.00037	0.00010	0.00257	0.00040	0.00003	0.00013
<b>5</b>	0.02557	0.00530	0.02854	0.03653	0.04835	0.02076	0.00369	0.02284
<b>#5</b>	0	0	0.00001	0.00001	0.00000	0.00027	0.00003	0.00002
<b>b6</b>	0.00001	0.00000	0.00001	0.00003	0.00021	0	0	0.00002
<b>6</b>	0.00238	0.00168	0.00065	0.00342	0.03642	0.01261	0.00854	0.00410
<b>b7</b>	0.00062	0.00003	0.00001	0.00003	0.00043	0.00119	0.00000	0.00025
<b>7</b>	0.02025	0.00510	0.00035	0.00029	0.00323	0.01327	0.00448	0.00275
<b>rest</b>	0.01974	0.01096	0.01644	0.00706	0.03082	0.00487	0.00241	-

**N.B.** This table does not include continuations to chromatic pitches—consequently table values sum to 0.9883 rather than 1.0. The value “0” indicates no instances in the database, whereas “0.00000” indicates that at least one instance occurred.

## Surprise

Consider second, the *qualia* of *surprise*. Survey participants used the words “uncertain,” “surprise,” and “unexpected” to describe three chromatic pitches: the raised tonic, the lowered supertonic and the subtonic respectively. It is hardly a surprise that the least commonly occurring scale tones are the chromatic pitches. Once again, the qualitative descriptions of subjective experience appear to be associated with the observed statistical regularities in the music.

## Closure

Consider third, the *qualia* of *closure*. Aarden (2003) has shown that the Krumhansl and Kessler key profiles (Krumhansl, 1990) are best viewed as reflecting a sense of closure or pause. In the probe-tone method, the tone sequence is interrupted immediately after the sounding of the probe tone. In judging the “goodness of fit” for such probe tones, it is possible that listeners instead judge how well the tone provides an appropriate place to stop the sequence of sounds. Aarden (2003) has assembled compelling experimental evidence in support of this interpretation. In addition, the Krumhansl and Kessler key profiles correlate more strongly with the distribution of phrase-terminating

pitches, rather than with the distribution of pitches in general.

The pitches most likely to terminate phrases or melodies are the tonic, dominant, and mediant pitches. Once again, the qualitative descriptions provided by the survey participants do not allow us to calculate a quantitative correlation. Informally, however, we can observe that the descriptions “restful” and “home” are applied to the tonic and mediant pitches. Descriptions of the dominant pitch are less consistent with the *qualia* of closure.

## CONCLUSION

There appears to be a notable association between the subjective *qualia* reported by musicians and the basic statistical properties of scale tones for Western music. Scale tones described as surprising or unexpected have objectively lower zeroth-order probabilities of occurrence. Those scale tones characterized by musicians as tending, leading, or pointing, are more likely to be those tones that are objectively most highly constrained in their first-order probabilities. Scale tones described as stable or restful, are more likely to be those tones that exhibit a high probability of terminating a phrase or work. Many of the remaining *qualia* categories, including certainty, tendency, comple-

tion, mobility and stability appear to be readily interpreted as relating to the statistical properties of tones and tone successions. While other interpretations are possible, these informal observations are consistent with the idea that the subjective experiential *qualia* evoked by scale tones may be attributable to statistical learning.

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