

Time, Structure and Emotion in Music

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1 Introduction

Music is organized sound. Although this may seem simple, it appears that important aspects of music cannot be adequately explained by the science we know today. These puzzling properties include the way time seems to expand and contract, and the way strong emotions can unexpectedly arise. We aim to explain such phenomena using ideas from contemporary philosophy, cognitive science and physical science. A major theme is “qualia,” often defined as the non-objective aspects of experience¹. Music is ideal for research on qualitative experience, since many phenomena can be explored without elaborate equipment, taking advantage of our extensive experience with music. Section 3 describes some experiments of this kind, showing that qualia not only have odd properties, but also have far more structure and regularity than often assumed. Section 4 considers a recently discovered cognitive process called blending, and Section 5 sketches a theory of musical qualia and its generalization to consciousness.

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2 What are Qualia?

Western thought has long tended to suppress, ignore, or downgrade subjective experience, perhaps reaching a zenith in the behaviorist psychology of B.F. Skinner, which denied the existence of consciousness and sought to rely exclusively on objectively observable behavior. Similar approaches to music try to reduce it to objective properties, including pitch, volume, duration, attack and timbre, codified in the notion of “the note” as the atomic element of music, and “the score” as the piece itself. This is consistent with Descartes’ call to analyze phenomena into combinations of atomic parts [8], the logical atomism of Wittgenstein’s *Tractatus* [20], and dictates of the Vienna Circle. But such approaches fail to explain much of contemporary science, music, and art.

The most common definition of qualia is slightly more kind to experience than extreme forms of reductionism (e.g., [6]) which deny their existence: qualia are what remains after all objective features are subtracted, the “feeling” of experience, as opposed to its objective properties. However, most of us believe that our experiences of time and emotion are much more real than what can be given as numbers, even though it is often claimed that the objective measures are more real than our subjective feelings.

Philosophers often give simplistic examples, such as the feeling tone of an (allegedly) atomic perception, like a patch of red. But qualia in music are much more complex than that, ranging from whole pieces, through sections and phrases, down to fragments of notes, and they have a hierarchical structure, whereby some are included within others. Moreover, musical qualia exhibit

¹The word “qualia” comes from philosophy; its singular form is “quale.”

a remarkable range of emotions, not just happiness, sadness, excitement, confusion, and humor, but also many subtle feelings for which we have no words. The reduction of qualitative experience to what is left unexplained by science makes it what sociology calls a “residual category,” as in the categories “Other” and “Not Applicable” at the end of a questionnaire choice list, a sort of statistical garbage can, filled with things that may be strange, unknown, or interesting, in ways not easily described [4].

3 Qualia Experiments

Our lecture-demonstration at Keio included seven experiments², consisting of short piano segments, to exhibit properties of qualia; see the score in Figure 1. The first experiments placed “the same” note, middle A (440 cycles) in different contexts, always played four beats *moderato* (moderate tempo) and *mezzoforte* (medium loud). These Italian words are part of a large family used in scores, including *doloroso* (sad) and *con spirito* (excitedly). Although some terms seem more precise than others, none has an exact meaning in physical terms. Even the frequency of middle A is approximate, particularly on instruments like violin and voice where vibrato is normal.

The second experiment added notes underneath the four beat *moderato*, *mezzoforte* middle A, to form chords, including a major triad (“bright”), a minor triad (“a bit sad”), a major seventh (“jazzy”), and two more complex chords (“tense” and “dense”), the point being that the notes underneath greatly changed the character of the A on top³.

The third experiment had two stimuli (numbers 3, 4 in the score), each a scale followed by the A. The first used an ascending major scale with increasing volume, the second a descending minor scale with decreasing volume. This showed that what comes before a note can greatly change its feeling. The fourth experiment showed that what comes *after* a note can also greatly change its feeling. Its first stimulus followed the A by a simple major scale cadence⁴, whereas the second followed it by an atonal sequence. The second sequence seemed to leave the A energized and exposed, whereas in the first, the A seemed almost to disappear.

The fifth experiment (numbers 6, 7 in the score) showed that the apparent duration of a note can be changed by what comes before it. Here the first stimulus consisted of a slow cadence concluding with the usual A, and the second of a similar cadence, but with notes of decreasing duration. The A in the second stimulus seemed much longer than in the first, even though they had exactly the same physical duration (about 2 seconds). The sixth experiment had a single stimulus consisting of five repetitions of a single measure having the usual A on top and a four times repeated F underneath it, all played *moderato*, *mezzoforte*. Here the simple phrase is first expected to become part of a larger unit, but under repetition becomes itself a unit, then becomes boring, and finally ongoing background that can be ignored. This illustrates the retroactive modification of prior material.

The final experiment was a short classical sonatina written by Ryoko. The audience was asked to listen for the second entrance of the first theme, which (for most listeners) has a pleasant, refreshing quality – we are glad to encounter something we already know, a landmark in an evolving landscape. There are many instances of A, but they are hardly perceived as such.

Properties of qualia and subjective time drawn from these experiments are listed below; some may seem counter-intuitive. The experiments show that qualia have structure and exhibit lawful behavior; they are *not* an unfathomable residual category. They also show it is far from adequate

²Although we use language from experimental psychology such as “stimulus,” we do not compute statistical levels of significance, because the results are immediately obvious to most listeners in the audience.

³The attributed feeling tones in parentheses are only approximate descriptions that vary somewhat among persons.

⁴This technical term indicates a sequence of notes concluding a section, e.g., by returning to the key note.

to say that the quality of experience depends on context⁵.

1. Qualia are created during perception and interpretation; they do not exist independently.
2. Qualia are associated with segments of experience, but not all segments are qualia, only those considered significant.
3. Qualia are hierarchically organized: some are parts of others.
4. A quale can be retroactively “swallowed up,” or incorporated into, another quale, ceasing itself to be a quale.
5. Qualia have different *saliencies*, which indicate their relative significance; these can change over time.
6. There is no relation between the saliency of a quale and its size; very salient qualia can be any size.
7. Consciousness consists of qualia, and the degree to which we are conscious of a quale is proportional to its saliency; this is called the C (for Consciousness) Hypothesis in [13].
8. Each quale has as its context the larger grain qualia in which it is embedded, and most qualia have an internal structure, consisting of its sub-qualia.
9. Foreground and background (or context) are determined by the structural organization of qualia: background consists of low saliency qualia that contain large saliency qualia; foreground and background are not pre-determined.
10. Emotion is a central, even defining, feature of qualia: a segment of experience is meaningful if and only if it has an emotional tone⁶. There are systematic regularities to these emotions, having an evolutionary explanation, as discussed in Section 5.
11. Listening is a highly *active* process, which segments an ongoing stream of sound into qualia with associated saliencies; it is a process of understanding, of sense-making, not merely of signal processing.
12. Qualia are *not* the leftovers of objective experience: on the contrary, they are the fundamental blocks out of which experience is composed.

The experiments also yield some observations about time:

13. The structure of the experience of time is the structure of the qualia involved.
14. Time is noticed mainly at transitions between qualia.
15. Time goes more slowly inside more salient qualia.
16. The sense of time can seem to disappear at moments of great intensity.

These observations support a definition of qualia (following [13]) quite different from the traditional one described earlier:

Qualia are the hierarchically organized constituents of conscious experience, each with a saliency and an emotional tone.

What is sometimes called the “problem of qualia” or the “hard problem of consciousness” [5] is to explain in purely objective terms something that has been defined as not having any objective content. We believe this is a pseudo-problem that goes away when a better definition of qualia is used. Our musical experiments allow direct experience of qualia in the sense of the above definition,

⁵Indeed, this way of using the word “context” makes it another residual category, reflecting an unwillingness or inability to carefully analyze the phenomena in question.

⁶Damasio [7] demonstrates the functional importance of emotion, for example, in memory and reasoning.

and we can also construct theories to predict the results, as in Section 5. Visual experience seems similarly structured into parts, which may be called qualia, are hierarchically organized, and have associated saliencies and emotional tones. As indicated in item 7 above, this leads to a new theory of consciousness in which there is no analog of the hard problem.

In formal logic, the Law of Identity is stated as “ $A = A$ ”, meaning that every object is equal (or identical) to itself. But this law does not hold for qualia, because they are necessarily experienced under different histories. We might write “ $A \neq A$ ” to remind us of this⁷. The experiments of Section 3 demonstrate that each instance of the note “A” is different, even though they are physically identical. The Law of Identity may apply to objects of modern science and technology (e.g., numbers), but not to human experience. It appears that human senses have been optimized by evolution to find differences, in which case identity is the failure to find a significant difference. Hence we can say that an “object” is a failure over time of a system of significant differences; indeed, this can serve as a definition of “the same,” as illustrated by the fifth experiment, in which we can experience the construction of an object that persists over time⁸. For qualia, difference is primary and identity (or more precisely, similarity) is secondary, whereas common sense considers that the identity of objects is unproblematic, while discovering difference may take effort. The experiments also show that the “A” can lose its individual identity by being absorbed into a more significant quale, needing effort to perceive it as an individual quale⁹.

4 Blending and Metaphor

We argued that the essence of music lies in its qualia, and that qualia divide experience into salient chunks hierarchically. An important problem for the scientific study of music is to explain this division of experience, accounting for the emotional tones of qualia, and the fact that listeners can fail to understand some music. Section 5 sketches a theory originating in [10] and elaborated in [13] that attempts such an explanation, while this section considers how qualia combine, which is quite different from how parts combine in building a bookcase, solving a jigsaw puzzle, or analyzing syntax. We build on recent studies in cognitive linguistics of how meanings of natural language constructs are composed from meanings of their parts.

Fauconnier and Turner developed conceptual blending [9], in which relatively small, transient structures called conceptual spaces, combine or “blend” to yield a new space that may have emergent structure. Simple examples are words like “houseboat” and “roadkill,” and phrases like “artificial life” and “computer virus.” Blending is considered a basic human cognitive operation, invisible and effortless, but pervasive and fundamental, for example in grammar, reasoning, and combinations of text with music [21].

An algorithm for conceptual blending has been developed for natural language generation [14]; when applied to the spaces for “house” and “boat,” it finds 48 interesting blends, including of course “houseboat” and “boathouse,” but also many others for which English has no simple phrase. This large number of possibilities implies that additional mechanisms, such as the “optimality principles” of [9], are needed to select those best for a given situation. Similar considerations apply to music, but since conceptual spaces cannot capture hierarchical structure, the qualia theory of [13] uses the structural blending of [11, 12] and the hierarchical information theory of [10].

⁷If we index instances of “A” by time and place perceived, then “ $A = A$ ” becomes trivial and has little value.

⁸Something similar happens in the third of Webern’s *Five Pieces for Orchestra*, where what at first seem like irregular percussive sounds come to be seen as the workings of some strange machine, such as a broken clock.

⁹Hence the Transitive law is not valid for the part-of relation, i.e., “ $x < y$ and $y < z$ implies $x < z$ ” is false for qualia. More technically, the laws of classical mereology fail for phenomenological experience. Heidegger [15] discusses some related issues.

5 Anticipation, Evolution and Emotion

The Qualia Hypothesis¹⁰ of [13] says that qualia are the components of a hierarchical description of experience, composed using a given culturally determined basis, containing both atomic elements and transformations of chunks into other chunks, with saliencies assigned to each chunk¹¹. An important qualification is that this formalization is a *model*, not a definitive description of reality; models are constructed by humans for particular purposes.

An ideal listener could construct a simplest hierarchical description for any music, and continuously reconstruct it in real time. But humans have limited processing power and memory, and therefore can only approximate the ideal (though repeated listenings can get closer, and careful study might even achieve it). However, humans can anticipate¹², not just simple physical actions, which animals have, but also the behavior of other humans. This capacity arose from evolution and natural selection to enhance survival; it rewards correct anticipation with pleasure, arouses curiosity when anticipation fails mildly, arouses doubt and uncertainty for greater failures, and arouses fear in case of significant failure in a dangerous situation. These instinctive responses are emotion, triggered by comparing anticipation with reality; this is the E (for Emotion) Hypothesis of [13].

Recent work with Borgo [3, 2] combines these ideas with those in Section 4 and nonlinear dynamical systems theory [1, 18], an area concerned with phenomena like weather that are difficult to predict and subject to sudden shifts among states that may have very different qualities. Our current research on improvisation is especially concerned with *phase transitions*, which are the periods between relatively homogeneous segments, and *bifurcations*, where a system is delicately poised between evolving along two (or more) quite different paths; a common goal of improvisers is to give listeners the subjective experience of such moments. We have found certain signs exchanged among musicians to signal bifurcation points, including often subtle cadence-like figures. The theory also uses the hierarchical complexity function mentioned in footnote 11 to measure of the potential energy of states; this gives the observation that a segment of music is “high energy” (or “low energy”) a precise interpretation. Data for these studies comes from free jazz improvisation performances (especially the Sam Rivers Trio), but the theory seems equally appropriate for many Western musical styles developed after the mid-twentieth century, as well as earlier styles (see examples in [10]), and perhaps even non-Western musics.

6 Conclusions

Consciousness is a great unsolved problem of science today [6]. Using music as a concrete example, we argued following [13] that consciousness has much more structure than generally supposed, including a hierarchical decomposition where each part has its own saliency and emotional tone; we also sketched an evolutionary basis for this, and showed how notions like context, foreground, and background arise naturally.

¹⁰This is actually a combination of the Main and Qualia Hypotheses in [13].

¹¹The sum of the cognitive complexities of the components of a description is a measure of total complexity, having the formal properties of an information theory in the classic sense of [19], despite its quite different basis; this suggests interesting links with the old but still influential [17]. For details, see [3, 2, 10].

¹²Husserl, a philosopher in the phenomenology tradition which explores the subjective structure of human experience, considered time [16], noting a subtle combination of anticipation with memory, within which he identified a component called “fresh memory” which holds about ten seconds of sound in a form that allows the past to be reheard in the present. Modern psychology has confirmed these observations.

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Figure 1: The Experimental Stimuli

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