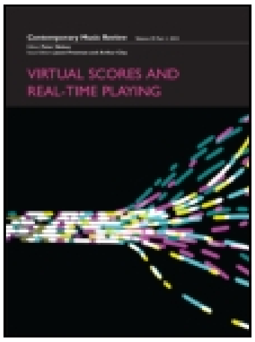


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# Simplicity and complexity in music and cognition

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There are three areas that have been touched upon in this conference about which I will comment. First, there is the issue of what I have come to call the "skimpiness" of stimuli in many experimental studies of music cognition. Second, there is the issue of whether there are cognitive universals constraining musical understanding and structure, and if there are, what we should make of them. Third, I take up the nature of mental representations involved in music cognition, suggesting that a considerable amount of the knowledge that guides listening and provides an interpretation of what we hear is implicit and procedural, rather than explicit and declarative.

KEY WORDS: Cognitive universals, stimulus complexity, procedural knowledge, explicit vs. implicit cognition, pitch perception, mental representations.

The three areas that I touch upon in this paper – the representativeness of stimuli in psychological experiments, the nature of the mental representation of musical structure, and the possibility of universals of cognition impinging on musical structure and cognition – are all interrelated. I shall return at the end to a discussion of some of those interrelationships.

## The representative nature of stimuli

It has often been noted, here and elsewhere, that the stimuli used in psychological experiments purporting to investigate perception and memory for music are typically "skimpy" in comparison with "real" music. That is, they are usually brief, monophonic, and of uniform rhythm, loudness, and timbre, while real music is extended in time, usually involves more than one voice, and varies considerably, continuously, and subtly along numerous perceptual dimensions. When this observation is tied to a criticism of psychological research on music cognition the argument continues with the claim that since the stimuli are so different from music, experiments cannot tell us anything about *music perception,* but merely about some aspects of human information processing. To learn about music cognition, this argument goes, we must use as a stimulus actual music in all its complexity.

The counter-argument runs along the lines presented by Krumhansl (this volume). The skimpiness of stimuli in experiments stems from the desire to isolate important variables that affect cognition – to separate those variables from other variables present in complex music that may, within the style with which we are working, be correlated with them. For example, there are temporal cues that indicate the completion of a phrase, and pitch cues. In actual practice those two variables seldom vary independently of each other. Therefore, to separate the effects due to each we must contrive "unnatural" sets of stimuli. Further, once the variables are isolated we seek results that will generalize to a wide range of actual music. This leads us to represent critical variables in rather stark form in our stimuli, unaffected by the context in which they find themselves, and lacking the subtle alterations that context would impose.

This approach of using skimpy stimuli will work as long as the cognitive processes they evoke actually *are* components of the whole process involved in listening to and understanding music. What is important is the *representativeness* of the stimuli as well as that of the processes involved in interpreting them. For our claim to be investigating *music* to hold, the contrasts defined in the stimulus set must reflect contrasts relevant to musical structure, and the cognitive processes by which the stimuli are interpreted must reflect ones that figure in music listening. Whether we are successful in capturing essential properties of music is an empirical question. That is, as we make our stimuli more and more complex, taking them in the direction of actual music, the effects we had discovered with simpler stimuli should not disappear, but rather become qualified with contextual conditions of applicability. Simplified stimuli are successful to the extent that they represent relevant real world features accurately.

It is important to remember in this connection that we need not rely on just one set of stimulus representations to get a given musical feature. In general, we require a set of converging operations (Garner, Hake & Eriksen, 1956) to focus on an hypothesized internal process such as pitch encoding or temporal pacing. The use of converging operations to delineate complex internal processes has become a standard strategy of cognitive psychology. Its use here means that we don't have to settle for just one level of skimpiness – just one type of abstraction – in our stimulus representations of the features of music. Converging studies provide the opportunity for a variety of representations of one and the same musical phenomenon, each representation capturing it from a slightly different angle, with different nuances of emphasis. In that way varying contexts are sampled piece by piece, rather than all at once.

Thus, one direction the empirical program of applying cognitive psychology to music could take is to begin with the skimpy in an attempt to identify essential features, and then expand our stimulus patterns by including more and more complexity, continually monitoring the effects. The empirical program could equally well proceed in the opposite direction, starting with rich musical stimuli and gradually abstracting simpler features. Dowling & Bartlett (1981) did that, for example, in their investigation of memory for melodic contour versus exact intervals in long-term memory for melodies. They started with passages excerpted from Beethoven String Quartets and found the surprising result that listeners remembered intervals quite accurately. Then to specify the conditions on which that result depended more precisely, they proceeded to repeat the experiment with abstracted, simplified stimuli under more tightly controlled contextual conditions.

In this process of adding complexity the computer is invaluable. Computers provide detailed control over stimulus parameters and facilitate the exploration of increasingly elaborate structures. And given the technological capability to journey between the skimpy and the elaborate, we rely on theory to chart our course, pointing out features that are likely to be important and contextual aspects that should not be ignored. The relationship of theory and experiment is a two-way street. Experiments provide tests of theories, and theories show experiments how to define phenomena. In this venture, theories such as those of Narmour and Lerdahl are indispensable.

## Universals in music cognition

The question of whether there are universals of music cognition, and in what sense they might constrain musical composition and practice, inevitably arises in discussions such as this. I myself am responsible for listing some of the universal features that appear in an overwhelming number of musical cultures around the world, including octave equivalence, seven or so discrete scale steps per octave, and hierarchical rhythmic organization (Dowling & Harwood, 1986, ch. 9). I have no doubt that these common features of the world's music have common origins in the structure of the human nervous system, as developed in its encounters with the world. To take the example of octave equivalence, it doesn't matter whether the octave is abstracted from complex sounds by the ear or whether it is innate; by adulthood virtually everyone treats the octave as a special relationship. And knowing that listeners are highly likely to judge octaves in a particular way is useful to composers and instrument designers.

Some of the proposed universals are more flexible, more malleable by experience than others. Thus the octave seems to be quite fixed, and the same size octave appears to be used the world over. Constraints on musical scale structure, in contrast, seem more general and to admit of a great many possible instantiations. The way the octave is filled in varies considerably from culture to culture. I think we can attribute this to the octave's being closely tied to the physical stimulus and to the innate structure of the auditory system, while the choice of scale intervals depends on more general constraints on human information processing that are not specific to music nor even to audition. The latter type of more flexible universal affords more possibilities for "bending" through perceptual learning. Thus for example, Schoenberg's dodecaphonic system increases the number of intervals that are used within the octave, but leaves the octave itself intact. Lerdahl's paper (this volume) outlines the way some of the more general structural constraints applicable to tonal music may be operating as well in atonal music.

Having said all that in defense of universals, I think we need to take seriously de la Motte's caution concerning them, which she voiced at the symposium. While remaining aware of universals as an empirical indication of highly likely states of our listeners, we still need to retain freedom of choice concerning their application. It would be sad indeed if composers were to be constrained by some list of what the general public is used to, in the way designers of utilitarian objects such as automobile seats are constrained by human factors, considerations such as the average length of the human torso. The composer is more like the designer of household furniture, who is free to decide that people might try a "chair" in which the knees provide much of the support, or to invent body-support devices for fanciful extra-terrestrial creatures. As Harry Partch (1974) commented, it would be unfortunate if composers had to be constrained in the choice of pitch intervals by the abilities of the least discriminating in the general population. The way to extend the range of human capacities is to explore new tonal relationships and let perceptual learning catch up.

In considering cross-cultural universals we should remember that there are large individual differences among people for the various cognitive and sensory capacities, and that a given person's strategy for processing a stimulus varies with its contextural setting and the person's goals in listening. To take one example, the quarter-steps that fall between the semitones in the standard Western diatonic scale are unusual and the listener's usual modes of cognitive processing. When such quarter-steps are presented as target pitches in a very rapid melodic sequence in which attention is narrowly focused and auditory processing is forced to operate quickly, the quarter steps that occur are heard as assimilated to neighboring scale pitches. However, if the stimulus is slowed and the auditory system is given more time, then quarter-steps are processed quite accurately (Dowling, Lung & Herrbold, 1987). Here context has a pronounced impact on how nonstandard elements are heard.

An additional issue that bears on this discussion, as well as on the previous discussion of experimental skimpiness, is that psychologists like myself often assume that cognitive processing (whether consciously explicit or not) proceeds in an analytic mode – that like Schumann's "ideal listener" the brain reconstructs the score as it goes along. This assumption feeds a theoretic position built on the experimental analysis of the brain's feature analysis. Much can be learned this way, but we should not forget that the brain and mind is not always so precise and analytic, and that cognitive processing can operate effectively on a more global level. Thus sound images (in Bayle and Petitot's sense; cf. their chapters, this volume) can be heard and remembered episodically (so that we can recall their occurrence and recognize them when they recur) without their having to be analyzed at a micro level. Just because the use of a particular microtonal interval makes such a sound image distinctive, doesn't mean that the brain has a systematic way of encoding such intervals. The types of universals listed as cognitive constraints refer generally to constraints on *analytic* processing, and not on ways of producing interesting or beautiful sound images. Such images *may* lend themselves to auditory analysis, but they also may not. But inaccessibility to auditory analysis does not necessarily rob an image of its cognitive effectiveness.

Because of human flexibility in perceptual learning and processing strategy we should, as de la Motte suggests, be very cautious about imposing rigid extra-musical constraints on musical structure.



## The nature of mental representations

Turning to a discussion of mental representations of musical structure, I will begin by introducing the distinction mentioned by Krumhansl between declarative and procedural knowledge. Declarative knowledge is explicitly accessible to consciousness – we can say what it is we know; for example, that Josef Haydn and George Washington were both born in 1732. In contrast, procedural knowledge is embodied in how the nervous system does things; for example riding a bicycle. Procedural knowledge is stored in sensorimotor schemes for the analysis of sensory input and the generation of organized behavior. Though for some abilities we develop parallel and largely consistent bodies of declarative and procedural knowledge, many abilities are represented only in one or the other form and the accessibility of one representation in the other system is severely limited. Piaget (1974/1976) provides a dramatic example of this limited access: though everyone knows how to crawl, few can tell you the order of placing the hands and feet when crawling. Further, even when a given domain of knowledge appears in both systems there is no guarantee that identical information is stored in both guises. Leonard Bernstein recounts amusing differences of conceptualisation by different members of the Vienna Philharmonic concerning the playing of waltzes, for which we can suppose agreement in practice. One said, "We stress the second beat;" while another said "The first beat is stressed and the third beat is held" (Knoelke, 1971).

Over the past few years I have gradually come to see pitch encoding less as involving declarative knowledge and more as procedural achievement, much like the nonverbal cognitive processes as described by Marin (this volume). That is, rather than thinking of the tonal pitch system as a separate knowledge structure used to interpret sense data after it has been encoded, I have come to see the tonal pitch system as embodied in the very way pitches are initially encoded. That is, the procedures for pitch encoding embody the schematic representation of tonal pitch. I am led to this conclusion by general considerations concerning the rapidity with which pitch encoding is accomplished, the typical conscious experience of pitches as already encoded in the tonal system (we hear a *do* or a *re* or a *mi* – we don't hear an undefined pitch that we later succeed in interpreting as a scale pitch), and the *gradual* efficacy of perceptual learning in improving pitch encoding. Long term familiarity with a musical style leads to the development of procedures for the perceptual organization of sounds, paralleling the organization encountered in the music (as Zenatti has suggested).

One piece of evidence that pushed me in the direction of thinking of pitch encoding as mainly procedural came from an experiment in which listeners were given the task of recognizing brief melodies. The melodies were framed by a chordal context that defined the tonal scale values of the notes, so that changing the context could change *do–re–mi* into *sol–la–ti*, or vice versa. Musically untrained listeners recognized the test melodies equally well whether or not the context had been changed and so appear to have remembered the melodies simply in terms of relative pitch values (and not tonal scale values). In contrast, listeners with about 5 years of musical training appeared to remember pitches in terms of tonal scale values; that is, when the context shifted their, performance declined to chance (Dowling, 1986). But though the latter listeners encoded the pitches in terms of tonal scale values, they could not have labeled the pitches with those values at all. Listeners with moderate training had developed a procedural scheme for tonal pitch encoding, without developing the parallel declarative system typical of professional musicians.

The notion of procedures for pitch encoding is quite consonant with the notions of brain modularity developed by Zatorre (this volume) and by Peretz & Morais (this volume). If pitch encoding is a declarative matter, involving a sort of dictionary for looking up the interpretations of sense data, then it can be handled in the nervous system like any general-purpose look-up device such as is used for the retrieval of memorized information. If, however, tonal pitch values are encoded procedurally in the auditory system, then the module that processes them can *only* be a special-purpose pitch module, and not a general-purpose device.

I believe that both musicians and psychologists have been slow to arrive at the idea of procedural knowledge as representing musical structure because, to use Eric Clarke's (this volume) term, we live in a "logocentric" culture. We tend to think of what we "really" know as what we can talk about, and to disparage knowledge that we can't verbalize. When we possess two representations of a musical structure, one declarative and the other procedural, we tend to prefer the declarative one because of its accessibility to theorizing and formal manipulation. We must come to realize that most of our brain representations of musical structure are first developed through years of perceptual learning in listening to and performing music, and that the corresponding declarative representations are typically in the form of rationalizations at the conscious level of subtler and richer implicit representations at the subconscious level. At the conscious level we inevitably discard information in the interests of clarity of formalization – information that the brain "knows" procedurally to be important and does not forget.



## Interrelationships

The procedural nature of mental representations puts more severe limits on the malleability of cognitive universals than would be the case if the representations were largely declarative. With declarative knowledge representations, any formal symbolic system could be represented. But music is primarily to be heard, rather than reasoned with, and one consequence of that is that music is primarily interpreted via an essentially auditory procedural scheme. Universals inherent in the structure of auditory cognition constrain what perceptual learning can accomplish, while perceptual learning can stretch the capacities of the procedural schemes (though such stretching is less than what declarative learning could accomplish with declarative schemes.)

The issue between procedural and declarative schemes also has implications for the skimpiness-of-stimuli issue. Procedural schemes are typically quite literal minded – they come to expect *exactly* the same stimulus configuration again and again. Thus abstracting essential features from musical patterns incurs the possibility that they will be missed by the procedural representation, making the strategy of abstraction a risky one, though all the more impressive when it succeeds.

Finally, the abstractness of stimuli in many experiments leads us to a caution concerning the empirical basis for claims concerning cognitive universals in music. We need to be sure that a purported universal operates in musical contexts, and not only when isolated from context in the laboratory. For example, the evidence that octaves of the same size arise in musical instrument tunings around the world is a valuable addition to evidence concerning precision of octave tunings of pure tones out of context. (Dowling & Harwood, 1986). It is only through such explorations that we can discover how universal such "universals" might be.

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