MUSICAL RULES AND PITCH JUDGMENT

by

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ABSTRACT

Observed psychoacoustic events are often incompatible with musical knowledge. The point has been made particularly in the realm of pitch theory. This paper will contend that it is not the case that musical knowledge does not apply to psychophysical tasks or that musical knowledge fails to correspond with musical practice. Rather, the judgment of pitch is the result of a complex decision involving both the identification of pitch pattern and the operation of a rule-based structural system assigning the functional values of pitches. Different tasks or task demands may assign different relative weights to the system's operators. Whatever the aesthetic merits of Western-European tonality, the experimental study of it uncovers a powerful system of pitch organization and reveals the delicate interplay between perception and cognition. Examples will be drawn from our work on interval and melody recognition.

My interest in this problem--musical rules and pitch judgment--stems not from a primary orientation towards the study of music and musical performance but from a general interest in how psychological systems pick up pattern information in their environment. That is to say, how do systems respond to periodicities or, in a more general sense, repetitive patterns in the real world? Considerable progress has been made in auditory and visual research towards the identification of pattern analyzers. In the realm of pitch perception, for example, both theory and data support the notion of periodicity detectors that respond to the temporal pattern contained by a complex waveform. However, studies of pitch memory have tended not to provide such evidence. When we examine the ability to recognize or to

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remember a sequence of tones, we encounter a number of paradoxes where findings from psychoacoustic research do not correspond with musical intuition and knowledge. The situation is surprising, because musical intuition and knowledge would seem to be an ideal source of evidence of our ability to pick up pattern invariants such as the equivalence of frequency ratio or musical intervals. Musical knowledge in our Western-European tradition includes a well-defined hierarchy of tones, chords, scales, and octaves. It suggests that the apprehension of this hierarchy is the basis of the perception of melody and of harmony. Early psychoacoustic experiments, on the other hand, gave quite a different picture of how the auditory system responds to tone sequences.

The lack of correspondence between the psychophysical mel scale and the musical scale has long been a subject of comment and debate. The mel scale does not preserve constancy of musical interval and with the mel scale it is not possible to construct harmonic music (Ward, 1970). But apart from the psychophysical scaling techniques there are other paradigms that also yield findings at odds with musical expectations derived from musical intuition, experiences or exposure--for example:

1. the absolute judgment of pitch--studies that led to the estimate of the channel capacity for pitch at about 2 bits (Miller, 1956; Pollack, 1952, 1953);

2. the delayed comparison of pitch (Bull & Cuddy, 1972; Wickelgren, 1966, 1969);

3. short-term memory for pitch (Deutsch, 1975; Massaro, 1975).

The overall picture portrayed by psychophysical studies is one of a system with exquisite sensitivity for temporal microstructure but with only a very limited capacity to preserve this information in memory--at any rate, little capacity to handle the richness of musical pattern.

When I review the problem in classes in psychology or in musical acoustics, a typical comment from the students is that the difference between psychophysical studies and musical knowledge must reflect the presence of sampling bias. That is to say, the psychophysical studies probably deal with listeners with no musical background, while musical knowledge is the product of an elite, esoteric, and possibly not entirely consistent set of theories developed by music theorists. Our experimental research has shown that sampling bias--musicians versus non-musicians--is only part of the problem. Another important and equally critical aspect of the problem involves a description of the pattern information available in the stimulus array itself (Jones, 1978). This notion was pointed out by Attneave and Olson in 1971 when they argued that even untrained listeners will respond to the logarithmic structure of a "meaningful" pitch pattern. So one task that we have set for our research is the definition of a meaningful pitch pattern.

Our experiments have looked at both the role of musical experience and the role of objective structure in determining the response to a tone sequence. The experiments tend to fall in one of two classes. The first class that I shall describe is one in which the structure of the tone sequence is apprehended or picked up across all levels of musical experience that we have studied. The levels of experience range from that of the professional musician to that of the average college undergraduate with no more than a year or two of music lessons that he or she would rather forget. In these experiments we compose short tone sequences; to describe these sequences we use the musical notions of diatonicism--membership in a scalar set of tones--and harmonic progression--lawful rules describing the order of the sequencing of harmonic units. Our typical procedure is to compose a sequence that is highly structured, highly tonal, according to musical rules, and then to generate a string of alterations of the sequence in which the rules are gradually relaxed, ignored, or violated. An example of such a set of sequences is given in Figure 1.

Figure 1 shows a set of 32 tone sequences in musical notation. They were presented in random order to two groups of 60 listeners each. One group was highly trained in music performance and theory, the other group was moderately trained. The tones were pure tones generated by a General Radio frequency synthesizer under computer control and the rate of presentation was 500 msec per tone. Each listener was asked to rate the perceived structure of the sequence on a 6-point scale, with 6 representing the upper end of the structure scale. The main points to be noted in Figure 1 are as follows (further details are available in Cuddy, Cohen & Mewhort (1981)). First, the sequences are listed in order of subjective ratings provided by the highly trained group of listeners. The sequence at the top of the left-hand column was given the highest rating of structure on the 6-point scale, followed by the sequences, in order, down the column and then the sequences, in order, down the right-hand column. For each sequence, the two numbers separated by a slash represent the mean ratings from the two separate groups of listeners. Second, the sequence accorded the highest structural rating is a diatonic sequence with the I-V-I harmonic progression, beginning and ending on the tonic, and with the leading-note-to-tonic ending. This type of construction, we have repeatedly found, leads to a perceptual judgment of a highly structured, highly organized tone sequence. Third, harmonic analyses of three professional music theorists are also given. As the sequences descend in rating of perceived structure there is an increasing divergence among the analysts.

Figure 2 shows a cross-classification of sequences derived from study of the results of the rating experiment. The rows of the figure represent levels of harmonic structure, going from a strong diatonic I-V-I progression in level 1 to multiple violations of the musical rules in level 5. The columns represent additional dimensions that we and others (e.g., Dowling, 1978) have found to be important determinants of psychological structure--contour, or the pattern of ups and downs, and excursion, or the distance in semits between the first and the last note. Annabel Cohen and I have recently reported a recognition study using these sequences (Cuddy et al., 1981). In this study each trial consisted of a standard sequence, randomly selected from the set of Figure 2, immediately followed by two transpositions of the sequence. One transposition was correct, the other contained an alteration of one note by plus or minus one semit. Here the task was to recognize the correct transposition. Other tasks that we have studied with these or similar sequences involve perceived ratings of structure, detection of a mistuning within the sequence and, finally, ratings of preference or "pleasingness" of the sequence. For all of these paradigms there is a common finding: the level of musical structure as defined by the key membership of the notes and the harmonic progression of the notes is a critical determinant of performance that holds across a variety of levels of musical training.

So far I have characterized musical structure in terms of scalar and serial rules. In a second class of experiments, the serial rules are dropped though scalar rules may be available. The absolute judgment paradigm is an example of such a case. The frequencies for the absolute judgment task may be selected without regard for correspondence on the musical keyboard, or they may be selected in accordance with a specific musical alphabet, e.g., the triad. No temporal constraints, however, are involved. The performance of the musician benefits from the presence of scalar structure in the tone-generating set, but that of the relatively untrained listener does not (Cuddy, 1971). In a current experiment we have come to the same conclusion for a task in which the listener must identify a randomly-ordered sequence of tones as being generated from either the major or minor pentatonic mode. Again we have an instance in which temporal constraints provide no information. To solve the task the listener must abstract the underlying scalar alphabet of the sequence; at least a moderate degree of training seems necessary to do this.

The conclusion to be derived from the above is that whether or not the tonal properties of a array are apprehended will depend in part upon the training (or predisposition) of the listener but also to a very large part on the nature of the task itself. Tonal structure, or what Bamberger (1978) would call the formal systematic framework of a tone set, is perceived by relatively untrained listeners provided the array contains temporal cues. Temporal cues doubtless include the order and direction of pitch movements as well as the subjective rhythmic groupings induced by a fairly rapid presentation rate. They assist the search for the tonic or fixed reference point against which individual pitches are compared and then assigned functional roles.

Exactly how temporal constraints or expectancies operate to facilitate the abstraction of tonal structure is not yet understood, nor is the question of how the trained musician operates in their absence fully answered. In the latter instance we suspect that the structures have been sufficiently internalized (in an imaginal manner) so that referents and anchors are available without need of their physical presence. But an important research issue concerns the interplay of pitch movement in real time with the abstract relations of tonality and the relative weight attached to each in the processing of melody.

There are several psychological benefits to be derived from the appreciation of tonal structures. One is that by this means our appallingly limited memory for frequency information is circumvented and overcome. Highly structured tonal sequences continually strengthen the sense of tonic, e.g., by repeatedly returning to the tonic at predictable time intervals, or by repeating the periodic structures related to the tonic. In a tonal sense, the sequence doh-mi- soh-doh is an embellishment of a single note, the low doh. Its pitch is not forgotten.

Second, in the presence of tonal structure, pitch discrimination is enhanced. We have known for a long time in psychophysics that discrimination between two frequencies is more accurate when tested with a fixed standard tone than when tested with a series of roving standard tones. Presumably the fixed standard becomes a perceptual anchor stored in some kind of permanent memory. Tonal structures make available a fixed referent system and discrimination may be performed with relation to this system. An implication for music listening is that in the presence of tonal structure one may have greater acuity for fine differences, alterations are clearer, and possibly enjoyment of a finely rendered piece is enhanced.

The aesthetic merits of Western-European tonality are of course a subject of contemporary debate. The psychological import of our research is that tonal systems reflect a powerful means of organizing pitch in memory so that patterns or regularities can be detected. Our work cannot say whether these abilities are innate or developed through exposure to everyday sounds. Research shows that there are clearly developmental trends (Gardner, Davidson & McKernan, in press; Serafine, 1980). But we do know that formal training in music is not necessary for the apprehension of tonal form if the latter is contained in the temporal properties of the objective sound pattern. For psychoacoustical research in our culture, a "meaningful" pattern may be defined as one that reduces easily to simple harmonic progressions. It is a moot point--but one of considerable relevance to contemporary composition--whether we can over-ride or default a tonal system once it is present.

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NOTES ON DEMONSTRATIONS

Example 1.

The sequences of Figure 2 are presented column by column. Note that the coherence of the first sequence of each column is gradually broken down as the musical rules are weakened, then violated.

The study employed pure tones but the effect of structure is easily demonstrated with a musical instrument.

Example 2.

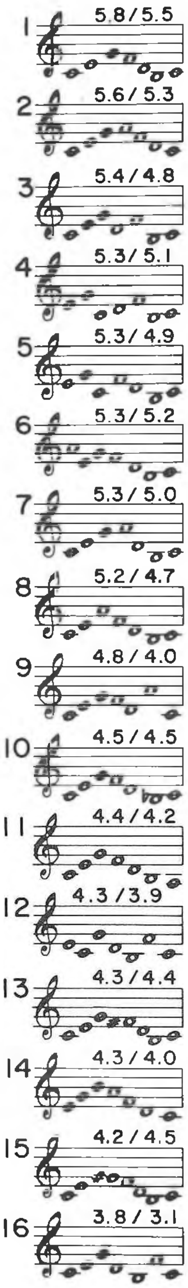
Sequences with the final note mistuned sharp by half a semit. Four sequences of low structure are presented first. They are the sequences of level S_5 of Figure 2 except that the penultimate note is raised from B flat to B. Sequences are presented across the row of level S_5. This is followed by four sequences of high structure--the sequences of level S_1 going across the top row. Note that the mistuning is more apparent with the highly structured sequences. (The alteration of sequences at level S_5 was done to produce an interval at the end identical to that contained at level S_1. The detection of mistuning therefore involves the same interval in both cases.)

Example 3.

Ten sequences are presented; first five with simple contour (three directional changes) then five with a more complex contour (five directional changes of pitch). Within each set of five there is a gradual degradation of structure, but note that structure deteriorates more rapidly than is the case for the levels of Figure 2. In the present example, the second and third sequence of each set are nominally diatonic but contain an unlikely progression VI-I. They may be considered modulating sequences, and in a recognition test proved to be as difficult as non-diatonic sequences. Such sequences provide examples of cases in which the search for a fixed referent is hampered by an unusual order of the tones (Cuddy & Lyons, unpublished manuscript available from the authors).

Note

The above examples accompanied the presentation and are available on tape. Contact the author for further details.



Sequence	Rating	ANALYST 1	ANALYST 2	ANALYST 3
1	5.8/5.5	I V_{7} I	I VII I	I V_7 I
2	5.6/5.3	I V_7 I	I II I	I II I
3	5.4/4.8	I V_7 I	I VII° I	V_7 I
4	5.3/5.1	I V_7 I	I VII° I	I VII I
5	5.3/4.9	I V_7 I	I VII° I	I VII I
6	5.3/5.2	V_7 I	VI V_7 I	V_7 I
7	5.3/5.0	I V_9 I	I V I	I V_9 I
8	5.2/4.7	I V I VI V_7 I	VI VII° I	VI VII_7 I
9	4.8/4.0	I V_7 I II	I II I	I II I
10	4.5/4.5	I V_{-7} I	I $VII^{\flat\circ}$ I	I V_{-7} I
11	4.4/4.2	I V_7 I	I VII° VI	I VII VI III II I
12	4.3/3.9	I V_7 I	I VII° I	I V_7 I
13	4.3/4.4	I V_7 I	I $VII^{\#5}$ I	I VII I
14	4.3/4.0	I VII III II I	III II I	III II I V_9
15	4.2/4.5	—	$I^{\#5}$ VII° I	—
16	3.8/3.1	I $V_{7tr.}$ I	I VII I	I V_7 I
17	3.3/4.1	two aug. triads	two aug. triads	whole tone scale
18	3.2/3.2	—	I V VI	VII
19	3.2/3.5	V	I II III $II^{\flat 7}{}_3$ I	II III
20	3.1/3.3	V_7 tr.	V_7 I VI V_7 VI	V_7 tr.
21	3.0/3.3	V_7 I	V I VI VI	I II
22	3.0/4.1	—	—	—
23	2.9/2.6	III V_7 I	III II I	VII VI
24	2.8/3.4	—	—	—
25	2.7/2.8	I II	V I II	I_7 II
26	2.6/3.3	—	—	—
27	2.5/3.1	V_7 I	II° I	V^{13} I VII^7 I
28	2.5/2.9	tr.	whole tone scale	whole tone scale
29	2.5/2.7	V_7	$^{\flat}VII^{\flat 7}{}_3$ V_7	—
30	2.4/2.6	—	I IV II VII I VI IV II V III V_7 VI	—
31	2.3/2.6	V_7	two dim. triads	two dim. triads
32	2.2/2.8	tr.	VI V IV V VI V VI V	—

NOTE: tr.: tritone — no analysis given aug.: augmented chord dim.: diminished chord

FIGURE 1: Thirty-two tone sequences in decreasing order of perceived structure as determined by listener ratings. Harmonic analyses of three professional music theorists are also given (from Cuddy, Cohen, and Mewhort, 1981).

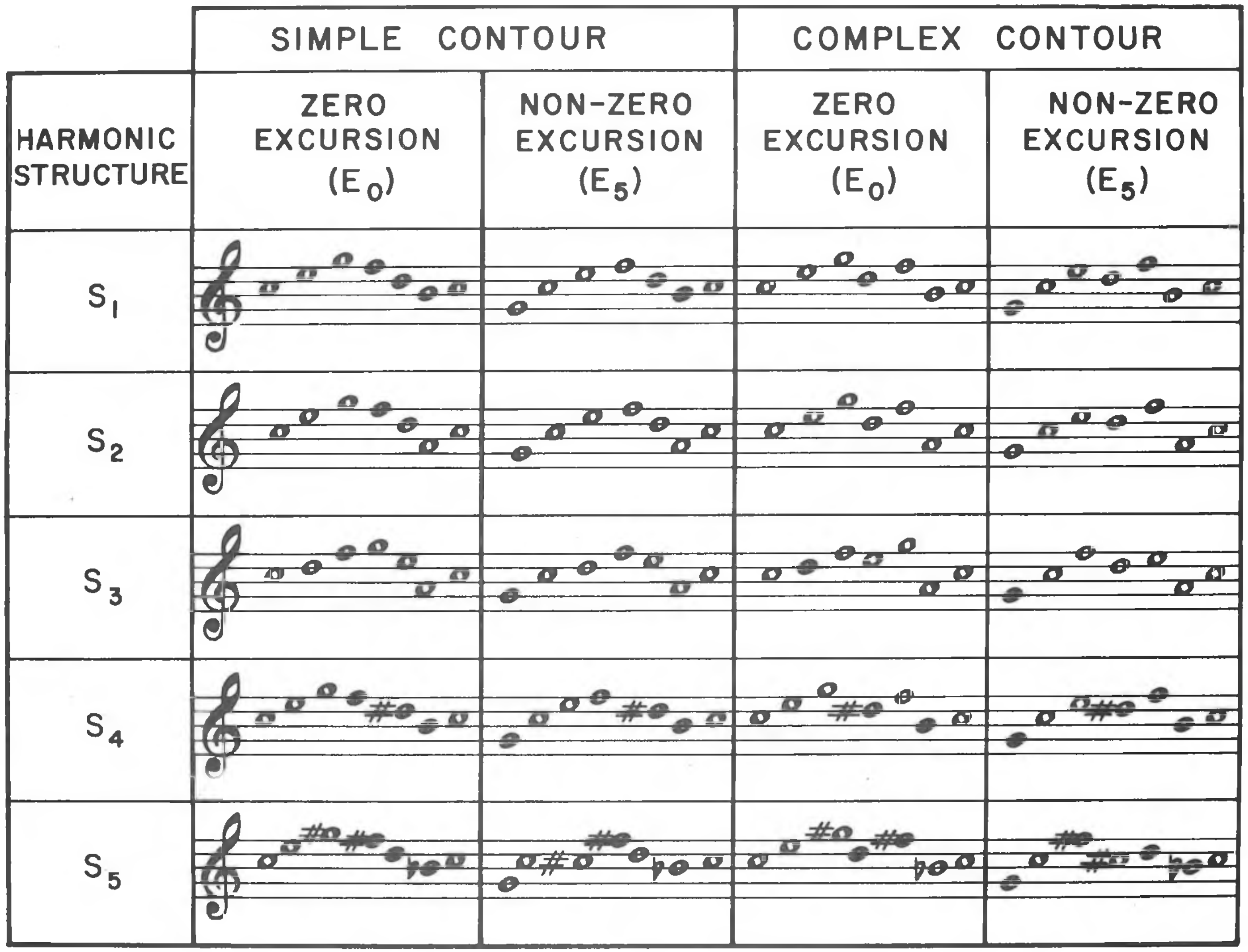


FIGURE 2: A cross classification of tone sequences according to harmonic structure, contour and excursion (from Cuddy, Cohen, and Mewhort, 1981).