CUES FOR PERCEIVING A KEY OF A MELODY

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ABSTRACT

Matsunaga and Abe (2002) indicated that key perception was affected not only by pitch set but also by its temporal sequence, and suggested that local characteristics of temporal sequence led listeners to perceive a specific key. The purpose of this study was to examine what kinds of local characteristics of temporal sequence would serve as cues in determining a key of a melody. Four musicians with absolute pitch listened to 450 melodic sequences and judged the most plausible key. These 450 sequences derived from the same pitch set [C, D, E, G, A, B] but differing in its temporal sequence. Our first analysis was for relations between the presence of specific intervals and key judgment. Results showed that the presence of specific intervals had no significant influence on listeners' key judgments. Our second analysis was for relations between the specific tones in a particular serial position and key judgment. Results indicated that the final tone of a sequence and a combination of pitches belonging to the tonic chord of the assumed key at the beginning guided listeners' judgement toward a specific key.

1. INTRODUCTION

Listeners perceive a key of a melody whether they can consciously name it or not. In the present study, we investigated the process whereby the listener perceives the key of a melody.

Some studies have shown that key perception is defined by pitch set (e.g., Hoshino & Abe, 1984; Krumhansl, 1990). In these studies, listeners tend to interpret all constituent notes within the given tone sequence as diatonic scale tones.

Others have shown that key perception is affected not only by the pitch set but also by its temporal sequence (e.g., Brown, 1988; Matsunaga & Abe, 2000, 2002). For example, Matsunaga and Abe (2002) used tone sequences consisting of the same pitch set but differing in its temporal sequence and required listeners with absolute pitch to judge the most plausible key. They found that the listeners' key judgment varied with the tone sequence between three or four groups those the tone sequences have the same pitch set. This result indicates that key perception is also influenced systematically by temporal sequence. This also suggested that cues for perceiving a key were some unknown local characteristics, rather than the order of pitches taken as a whole, shared with those tone sequences for which most listeners judged the same specific key.

The goal of the present study was to determine local characteristics of the temporal sequence that would serve as cues in identifying a key of a melody. We required participates to judge the most plausible key for tone sequences consisting of the same pitch set but differing in its temporal sequence.

2. METHOD

2.1. Participants

Four musicians with absolute pitch participated in this study (mean age =21.8). They had at least 14 (average of 16.3) years of musical training.

2.2. Materials

Tone sequences were prepared on the basis of three criteria. First, listeners must be able to feel a tonality for a given tone sequence. Feeling a tonality depends on whether the given tone sequence conforms to Western diatonic structure (e.g., Hoshino & Abe, 1984; Krumhansl, 1990). We used a diatonic pitch set, in which all tones were interpretable as constituents of one or more keys in Western music. Second, listeners must be able to perceive a specific key consistently for a given tone sequence. The experimental results in Hoshino and Abe (1984) suggested that pitch sets which consisted of six tones were adequate for listeners to establish a specific key and avoid a possibility of modulation. In this study, based on this suggestion, the number of components tones of the pitch set was decided to be six. Finally, listeners must be able to use not only cue of the pitch set but also one of its temporal sequence to perceive a key. We used an ambiguous pitch set on key perception, in which all tones could be interpreted as diatonic scale tones belonging to multiple keys. In this study, pitch set [C, D, E, G, A, B] was selected. All pitches of this set could be interpreted as diatonic scales tones of the following keys: C-major, G-major, e-minor, and a-minor. Both pitch set A [C4, D4, E4, G4, A4, B4] and pitch set B [D4, E4, G4, A4, B4, C5] were used, such that most intervals within an octave would occur. All possible permutations of different six tones [C, D, E, G, A, B] in a sequence would yield 720 types. In this study, 450 types out of the 720 possible types were randomly selected. Of these 450 tone sequences, 194 consisted of pitch set A, and 256 consisted of pitch set B.

Materials were 450 tone sequences from the same pitch set [C, D, E, G, A, B] but differing in its temporal ordering. All sequences were presented at the same tempo. The duration of each tone was 0.6 s, for a total of 3.6 s per sequence. All pitches were of equal intensity. Timbre of tone sequence was an acoustic piano.

2.3. Apparatus

Tone sequences as materials were created as MIDI files using sequencing software (Calkwalk) installed on Windows PC. The same computer controlled tone sequence presentation. All tone sequences were presented at a comfortable volume with speakers in a sound attenuating booth.

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2.4. Procedure

Participants were tested individually. The participants seated in front of speakers and used a printed list of the twelve major keys and twelve minor keys to record response. In each trial, a tone sequence was presented three times. The participants listened to the tone sequence, and selected the most plausible key from a list of the twelve major keys and twelve minor keys. After three practice trials, each participant performed 450 experimental trials in random order across four days.

3. RESULTS AND DISCUSSION

Preliminary analyses showed similar results for pitch sets A and B. Data were pooled across pitch sets in the current analyses.

3.1. Key Perception

As can be seen in Figure 1, key judgments were significantly limited to four (out of 24 possible) keys: C-Major, G-Major, a-minor, and e-minor. This confirmed that key perception for AP musicians was constrained by the pitch set.

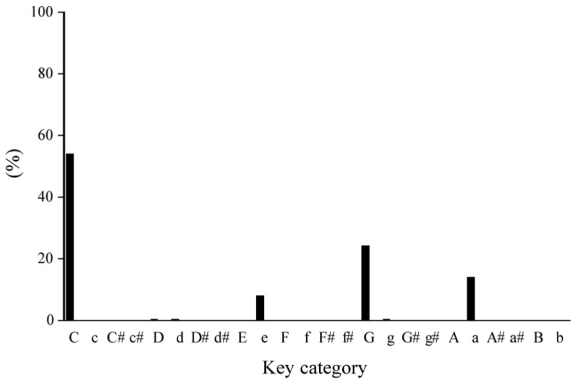

Figure 1: Proportion of key categories judged as the most plausible key for 450 tone sequences. Upper- and lower-ca letters denote major and minor keys, respectvely.

One hundred and sixty-nine tone sequences elicited agreement among at least three participants in their C-major judgment (hereinafter referred to as C-major group). 44 tone sequences elicited agreement among at least three participants in their G-major judgment (G-major group). Five tone sequences elicited agreement among at least three participants in their a-minor judgment (a-minor group).

The presence of these specific-key groups indicates that local characteristics of temporal sequences may have served as common cues in perceiving a specific key group.

3.2. Cues for Perceiving a Key of a Melody

3.2.1. The presence of specific intervals

Butler and Brown (e.g., Brown, Butler, Jones, 1994; Butler & Brown, 1984; Van Egmond & Butler, 1997) have argued that listeners rely upon rare intervals (i.e., minor second and tritone) more than common ones (e.g., perfect fourth and major second) in deriving a sense of tonal center, as these provide more reliable key information by unambiguously interrelating with a single diatonic set (Browne, 1981). More specifically, they have argued that the presence of a tritone functions as cue of key perception when it appears in temporal sequence implying goal-oriented harmonic motion of a type common in tonal music. As a preliminary step, we would focus on the presence of interval between adjacent pitches as their argument. That is, we examined whether the presence of specific intervals would function as cue for perceiving a key. In order to identify relations between the presence of specific intervals and the specific-key groups, we performed *Multiple Discriminant Analysis* with the stepwise procedure. Discriminate variables were 40 types of permutations of two pitches. Criterion variable was one key group with three categories: the C-major group, the G-major group, the remainder of the tone sequences except the specific-key groups (hereinafter referred to as remainder group). We eliminated tone sequences of the a-minor group from the 450 because they were few.

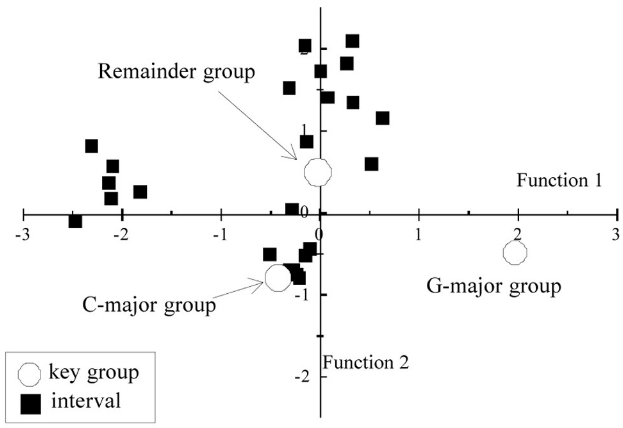

Figure 2: Two-dimensional plot representing relations between interval and key group from multiple discrimination analysis with the stepwise procedure. Average squared canonical correlation was .40.

Figure 2 shows a two-dimensional plot representing relations between interval and key group. The picture with key surrounded by intervals indicates that particular intervals possibly contributed to the participants' judgment on that key. As can be seen in Figure 2, some specific intervals possibly contributed to participants' key judgment for the C-major group (see third quadrant). No specific intervals possibly contributed to participants' key judgment for the G-major (see fourth quadrant). If the surrounding intervals of the C-major group functioned as cues of key perception, the surrounding of the G-major group had the same intervals with but different absolute pitches from those of the C-major group. As mentioned above, no specific intervals and the G-major group were plotted on the same quadrant. Thus, the results of this analysis suggested no effect of the presence of specific intervals on the participants' key judgment.

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3.2.2. Specific tones in a particular serial position

In this study, we also examined whether specific tones in a particular serial position of tone sequence would lead listeners to perceive a specific key.

The role of tones appearing in particular serial positions in key judgment. In order to identify relations between specific tones in a particular position and the specific-key groups, we performed *Multiple Discriminant Analysis* with the stepwise procedure. Discriminate variables were 36 types of tone-position (6 tones x 6 positions). Criterion variable was a key group with three categories: the C-major group, the G-major group, and the remainder group. We eliminated tone sequences of the a-minor group in this *Multiple Discriminant Analysis* because the y were few.

Figure 3 shows a two-dimensional plot representing relations between tone-position and key group. The picture with key surrounded by tone-positions indicates that particular tone-positions possibly contributed to the listeners' judgment on that key. Both D in the fifth position and C in the sixth position possibly contributed to participants' key judgment for the C-major group (see the second quadrant). G in the sixth position possibly contributed to participants' key judgment for the G-major group (see the first quadrant). The results revealed that the presence of tonic in the sixth position was common characteristics between the C-major and the G-major group. We also examined the a-minor group which were eliminated in this analysis. In four out of five sequences within the a-minor group, A occurred in the sixth position. These results suggested that the final tone of a sequence appeared to lead the participants to perceive a specific key.

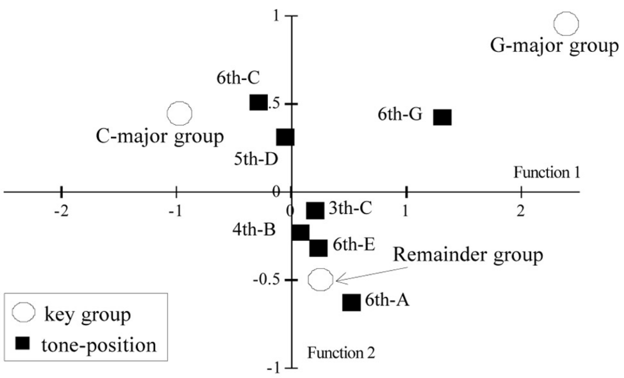

Figure 3: Two-dimensional plot representing relations between tone-position and key group from multiple discrimination analysis with the stepwise procedure. Average squared canonical correlations was 35.9.

Further examination of relations between particular serial positions of tones and listeners' key judgment. Each specific key group included some tone sequences of which the final tone was inconsistent with tonic of the target key: 110 (out of 169) tone sequences in the C-major group, five (out of 44) in the G-major group, and one (out of five) in the a-minor group. For the tone sequences of the C-major group (or the G-major group), it is conceivable that cues other than the final tone lead the participants to perceive C-major (or G-major). What were the cues? We analyzed the tone sequence of the C-major group (or the G-major group) to examine possible effects of tones appearing in serial positions other than the final position on listeners' key judgment. The following procedure of calculation was employed independently for the C-major group, the G-major group, and the remainder group. The percentage of tone sequences in which C (D, E, G, A, or B) occurred in each of the six positions to all tone sequences of the target key group was calculated, and accumulated per serial position. In the C-major group (or G-major group), the percentage of C (or G) inevitably was 100% in the fifth position, and the percentage of the others was 100% in the sixth position.

Figure 4 shows the results of the C-major group. The results revealed that C, E, G and A occurred up to the third or the fourth position while D and B occurred in the fifth or the sixth position. That is, a combination of C, E, G, and A would be followed by D and B in of a typical temporal sequence of the C-major group. Applied C-major frame to C, E, G, and A, these four tones could be interpreted as *do*, *mi*, *sol*, and *la* respectively in diatonic scale.

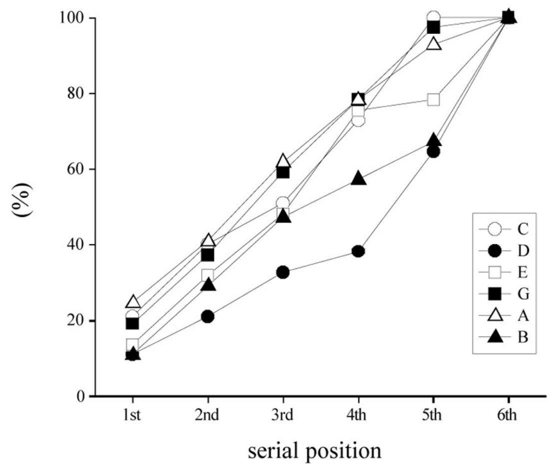

Figure 4: The accumultive percentage of tone sequences in which C (D, E, G, A, or B) occurred in each of the six positions in the C-major group.

Figure 5 shows the results of the G-major group. The results revealed that G, B and D occurred up to the second or the third position while C, E, and A occurred in the fourth and the fifth position. That is, a combination of G, B, and D would be followed by C, E, and A in a typical temporal sequence of the G-major group. Applied G-major frame to G, B, and D, these three tones could be interpreted as *do*, *mi*, and *sol* respectively in diatonic scale.

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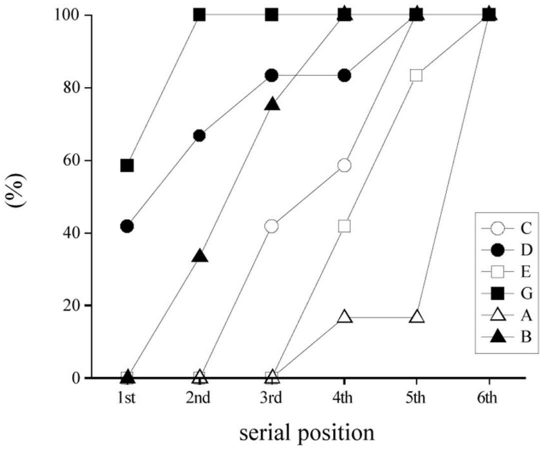

Figure 5: The accumultive percentage of tone sequences in which C (D, E, G, A, or B) occurred in each of the six positions in the G-major group.

The same analysis for the remainder group resulted in a completely different pattern (Figure 6).

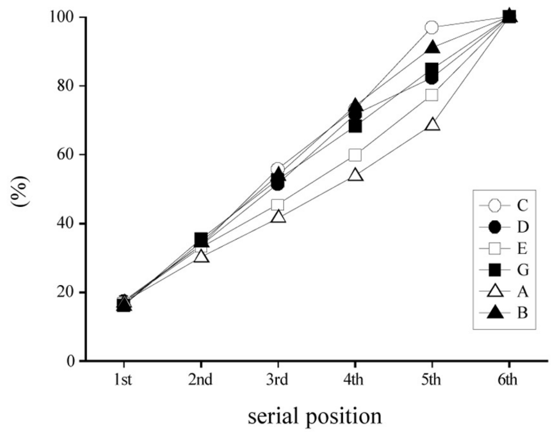

Figure 6: The accumultive percentage of tone sequences in which C (D, E, G, A, or B) occurred in each of the six positions in the remainder group.

These results revealed that a combination of *do*, *mi*, and *sol* at the beginning of a sequence was common characteristics between the C-major group and the G-major groups. Key perception appears to be determined by a combination of pitches belonging to the tonic chord of the assumed key at the beginning of a sequence, as consistent with earlier studies (e.g., Abe & Hoshino, 1990; Bharucha, 1984; Krumhansl, 1990).

4. CONCLUDING REMARKS

The results of the present experiment revealed that the final tone of a sequence and a combination of pitches belonging to the tonic chord of the assumed key at the beginning guided listeners' judgment toward a specific key. If the final tone of a sequence functioned as the primary determinant of key perception, it would be difficult for listeners to perceive a specific key until they actually heard the final tone. However, listeners could perceive a key even when they heard a couple of tones in the earlier part of a tone sequence (e.g., Hoshino & Abe, 1984). For this reason it is inconclusive whether the final tone affects listeners' key perception. We guess that the participants were fatigued from listening to many similar tone sequences so that they would use the final tone as an expedient cue of key perception. In this study, thus we would like to claim a combination of pitches belonging to the tonic chord of the assumed key as one of essential cues for perceiving a key.

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