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LISTENERS CAN DISCRIMINATE AMONG MAJOR CHORD POSITIONS[1]

TIMOTHY L. HUBBARD

Texas Christian University

Summary.—Listeners judged whether two sequentially presented major chords were the same. When both chords were based on the same root, listeners discriminated between different chord positions, e.g., root position, first inversion, second inversion. The ability of listeners to discriminate between chord positions suggests that harmonic equivalence of different chord positions does not depend on perceptual equivalence and instead arises from a more cognitive representation.

The harmonic structure of Western tonal music is based on chords, and one of the most common types of chords in Western tonal music is the major chord. A major chord may be constructed upon any note of the scale by choosing a tone to function as the base or root and then adding tones a major third and a perfect fifth above that root. For example, if the root is a C, then adding an E (a major third above C) and a G (a perfect fifth above C) produces a C major chord. However, it is not necessary to limit major chords to the third and fifth immediately above the root. As long as tone chroma are maintained, i.e., the pitches have the same letter names, the individual tones of the chord may be drawn from any octave. When the root is the lowest pitch, then the chord is said to be in *root position*. When the third is the lowest pitch, then the chord is said to be in *first inversion*, and when the fifth is the lowest pitch, the chord is said to be in *second inversion* (reviews of chord structure and inversion may be found in introductory music theory texts, e.g., Aldwell & Schachter, 1978; Kostka & Payne, 1995). These different chord positions are illustrated in Fig. 1.

The process of changing a root position chord into a first or second inversion chord involves an octave transformation of one or more of the individual tones that comprise that root position chord, e.g., a first inversion chord may be created from a root position chord by raising the root one octave in pitch. The harmonic equivalence of different chord positions assumes that a component tone drawn from one octave is equivalent to a tone of the same chroma drawn from a different octave. In other words, har-

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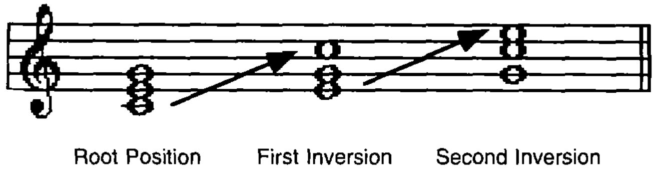

FIG. 1. Differences between a root position, first inversion, and second inversion C major chord. The root position chord has the root (C) as the lowest pitch, followed by the third (E) and the fifth (G). The first inversion is the same as the root position except the root is raised one octave (thus making the third the lowest pitch). The second inversion is the same as the first inversion except the third is raised one octave (thus making the fifth the lowest pitch).

monic equivalence of different chord positions assumes an octave equivalence of the individual tones that comprise those chords. Such an octave equivalence of different tones sharing the same chroma has been supported by studies involving generalization of conditioned responses in animals (Blackwell & Schlosberg, 1943) and humans (Humphreys, 1939), interference in tonal memory (Deutsch, 1973), rated similarity of pitches (Krumhansl & Shepard, 1979; Thurlow & Erchul, 1977), and confusions in tonal memory of listeners possessing absolute pitch (Miyazaki, 1988; Takeuchi & Hulse, 1993).

Octave equivalence of individual tones and harmonic equivalence of chord positions do not imply perceptual equivalence or indiscriminability, of course, and so the extent to which chords based on the same root but in different positions are perceptually equivalent is an empirical question (see also Deutsch, 1982). Both musically trained (Plomp, Wagenaar, & Mimpen, 1973) and musically unselected (Deutsch & Roll, 1974) listeners exhibit more difficulty in discriminating musical intervals that are inversions of each other than in discriminating musical intervals that are not inversions of each other, and on this basis we could predict that listeners would have relatively more difficulty in discriminating between different positions of a major chord. However, recognition of a previously learned melody may be disrupted if a given note in the melody is replaced by another note differing by an octave or an integer multiple of an octave, especially if the replacement does not preserve the melodic contour (Deutsch, 1978; Dowling, 1984; Dowling & Hollombe, 1977; Kallman & Massaro, 1979). The relative difficulty of listeners in identifying a melody presented in such "scrambled octave" form suggests that tones separated by an octave are not perceptually equivalent, and on this basis we could predict that listeners would have relatively less difficulty in discriminating between different positions of a major chord.

In the experiment reported here, listeners were presented a prime chord and a probe chord on each trial, and they judged whether the probe was the same as the preceding prime. If different chord positions are perceptually equivalent, then listeners should be less likely to discriminate between two chords that are based on the same root but are presented in different positions. Such a prediction is based on the increased difficulty of listeners in discriminating between pairs of otherwise identical intervals in which one of the tones is replaced by a tone of the same chroma drawn from a different octave, i.e., on the increased difficulty of listeners in discriminating between inverted intervals. If different chord positions are not perceptually equivalent, then listeners should be more likely to judge the probe as being the same as the prime when the probe and prime are presented in the same position. Such a prediction is based on an analogy between scrambled-octave melodies and chord positions: if the probe and the prime are based on the same root but are presented in different positions, then the probe could be considered to be a "scrambled octave" version of the prime.

Method

Participants

The listeners were 24 undergraduates who received partial course credit in an introductory psychology class in return for participation. The listeners were unselected for musical background.

Apparatus

Stimuli were synthesized by an Apple Macintosh IIsi microcomputer and presented to listeners via headphones (Radio Shack Nova-35).

Stimuli

Primes and probes were major chords consisting of a root pitch and the pitches a major third and perfect fifth above that root, and each chord was presented in either root position, first inversion, or second inversion form. The constituent tones of each chord were sine waves. Six different roots were drawn from keys equally spaced around the circle of fifths (C [261.63 Hz], D [293.66 Hz], E [329.63 Hz], F# [369.99 Hz], G# [415.30 Hz], and A# [466.16 Hz]), and each root was presented on one-sixth of the trials. In one-half of the trials the prime and the probe were drawn from the same key, i.e., shared the same root, and in one-half of the trials the prime and the probe were drawn from distant keys, i.e., the root of the probe corresponded to the tritone[2] of the scale based on the root of the prime. Each

[2]The tritone of a scale is 6 semitones (a half-octave) above the tonic of that scale. The tritone is not contained within the major scale based upon the tonic, nor are any of the elements of a major chord based upon the tritone contained within the scale based upon the tonic. For example, in a C major scale the tonic is C and the tritone is F#; a C major chord includes a C, E, and G, whereas a F# major chord includes F#, A#, and C#. Thus, a tritone (and a major chord based upon that tritone) is as harmonically distant from the tonic (and a major chord based upon that tonic) as it is possible to be and yet still be within the tonal framework.

listener received 216 trials: 3 primes (root position, first inversion, second inversion) × 2 keys (root, tritone) × 3 probes (root position, first inversion, second inversion) × 6 root pitches (C, D, E, F#, G#, A#) × 2 replications, and each listener received the trials in a different random order.

Procedure

Listeners were first given a set of 12 practice trials drawn randomly from the experimental trials. The listeners initiated each trial by pressing a designated key. The prime played for 2 sec., and after the cessation of the prime, the probe played for 2 sec. Listeners judged whether the probe was the same as the immediately preceding prime and pressed either a key marked *S* (same) or a key marked *D* (different) to indicate their response. After the experimental trials, listeners completed a brief musical background questionnaire in which they reported the number of years they had (a) played a musical instrument, (b) sung individually or in a chorus, (c) taken instrumental lessons, (d) taken vocal lessons, and/or (e) studied music theory.

Results

Listeners' responses in each category of the musical background questionnaire were summed to provide a musical experience score for each listener, and listeners were classified as either musically experienced or musically inexperienced on the basis of a median split of those scores. Listeners in the inexperienced group reported a mean of 2.3 yr. (range 0–5) of musical experience, and listeners in the experienced group reported a mean of 12.6 yr. (range 5–24) of musical experience.

The probabilities of a *same* response were analyzed in a repeated-measures analysis of variance in which prime, probe, and key were within-subjects variables and experience was a between-subjects variable. Experience was not significant, and the only variable with which experience interacted was prime ($F_{2,44} = 5.01$, $MSE = 0.01$, $p < .02$); experienced listeners were slightly more likely to respond *same* when the prime was presented in second inversion than were inexperienced listeners. Key strongly influenced judgments; listeners were more likely to respond *same* when the probe was based on the root ($M = .40$) than when the probe was based on the tritone ($M = .06$) of the prime ($F_{1,22} = 193.86$, $MSE = 0.06$, $p < .001$).

Prime was significant ($F_{2,44} = 3.74$, $MSE = 0.01$, $p < .03$); a *post hoc* Newman-Keuls test ($p < .05$) indicated that listeners were more likely to respond *same* when the prime was in first inversion ($M = .24$) than when the prime was in second inversion ($M = .22$). The probability of a *same* response to a root position ($M = .23$) prime was not significantly different from the probability of a *same* response to first or second inversion primes. Prime interacted with probe ($F_{4,88} = 145.18$, $MSE = 0.03$, $p < .001$), key ($F_{2,44} = 8.13$, $MSE =$

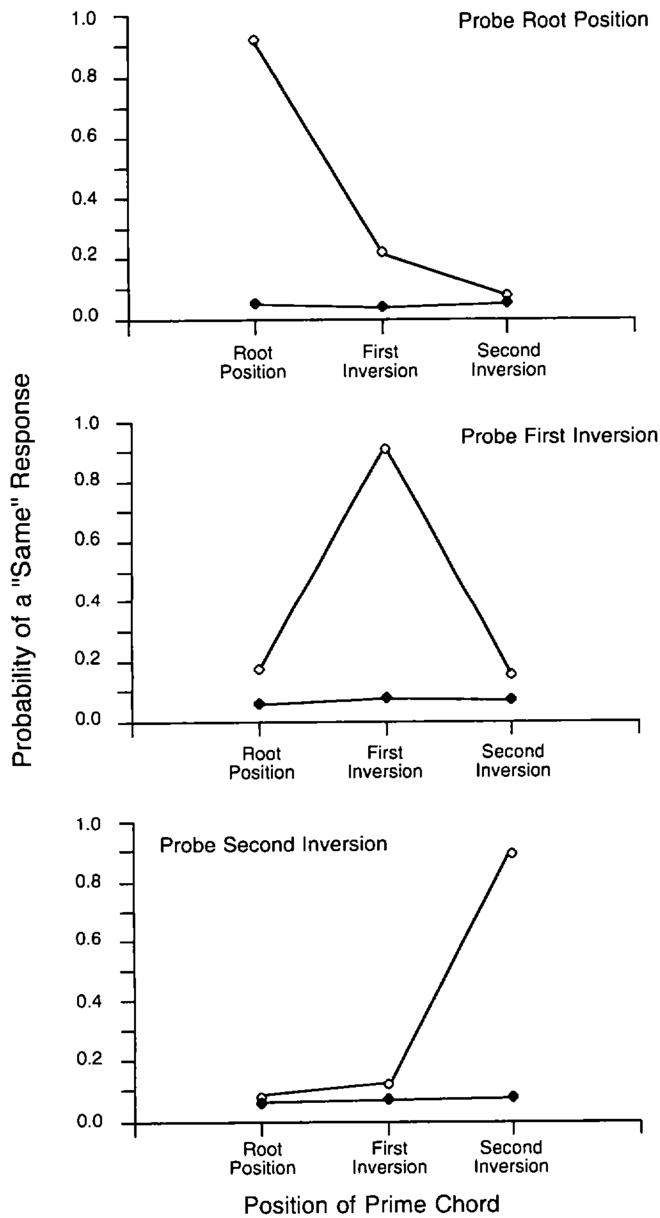

FIG. 2. The average probability of a *same* response as a function of prime chord position. Data for root position probes are displayed in the top panel; data for first inversion probes are displayed in the middle panel, and data for second inversion probes are displayed in the bottom panel. Data for same-key comparisons, i.e., prime and probe share the same root, are (◇) and for different-key comparisons, i.e., probe based on the tritone of the prime (◆).

0.01, $p < .002$), and with probe × key ($F_{4,88} = 105.70$, $MSE = 0.03$, $p < .001$). As shown in Fig. 2, listeners were more likely to respond *same* when the chord position of the probe matched the chord position of the prime when primes and probes were in the same key, and listeners were not influenced by chord position when primes and probes were not in the same key.

Discussion

When the prime and the probe were in the same key, i.e., based upon roots sharing the same chroma, then listeners' judgments were strongly influenced by whether the prime and probe were in the same chord position; listeners were much more likely to respond *same* when the position of the probe matched the position of the prime. This pattern is not consistent with the hypothesis that chords based upon the same root but differing in position are perceptually equivalent. When the prime and the probe were in different keys, i.e., based upon roots that did not share the same chroma (the tritone condition), then listeners' judgments were not influenced by whether the prime and the probe were in the same chord position. Of course, the failure to find an effect of chord position when the prime and the probe were drawn from different keys probably resulted from a lack of similarity in tone chroma between the prime and the probe rather than from any lack of perceptual or octave equivalence.

The findings that listeners can perceptually discriminate between different positions of a major chord and that such discrimination occurred in both experienced and inexperienced listeners offer an important constraint for models of the representation of musical pitch. Many cognitive models of pitch (e.g., Bharucha, 1987; Deutsch, 1969; Deutsch & Feroe, 1981; Krumhansl, 1990; Large, Palmer, & Pollack, 1995; Shepard, 1982) assume at least some octave equivalence of tones sharing the same chroma, but listeners' ability to discriminate between chord positions suggests that information regarding pitch heights of the individual tones comprising the chords must also be preserved. Whether this preservation requires the existence of additional representations at the chord layer that correspond to different chord positions, differential weightings of connections between individual tone and chord nodes, or some other mechanism remains to be determined. Harmonic equivalence does not depend upon perceptual equivalence, and this result is consistent with previous arguments (e.g., Bharucha & Stoeckig, 1987; Hubbard & Stoeckig, 1992) for a cognitive representation of musical pitch.

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