The Petrushka Chord: A Perceptual Investigation

CAROL L. KRUMHANSL & MARK A. SCHMUCKLER
Cornell University

Five experiments investigated listeners' capacities for perceiving polytonality, in which materials from more than one key are employed simultaneously. The stimulus materials were based on a particularly striking example of polytonal writing from Stravinsky's Petrushka; it outlines in arpeggiated form the tonic triads of two maximally distant major keys, C and F♯ major. The first experiment demonstrates, using the probe-tone technique, that the two component voices presented in isolation establish the expected keys and that when they are combined some influence of both keys is felt. The second and third experiments indicate, however, that when presented dichotically the two components cannot be separated perceptually; this is attributed to the two voices having the same rhythmic and contour patterns and being sounded in the same pitch range. The fourth experiment replicated the findings of the first three, using listeners very familiar with the particular passage. The final experiment tested an alternative theoretical account, the octatonic collection. Probe-tone ratings following an octatonic scale did not account satisfactorily for the data for the musical passage, but the hierarchy of priorities proposed by Van den Toorn (1983) fit the data better than the major key profiles, especially for the experienced listeners.

This series of experiments addresses the question of the nature of sound attributes listeners can reliably encode, organize, and remember. More specifically, the study is directed at characterizing responses to pitch organizations outside the tonal-harmonic tradition, which has been the focus of the great majority of studies in the psychology of music. The organizational device considered is polytonality—the simultaneous employment of materials from more than one key. This device raises an issue familiar to information processing psychology; namely, what capacity do perceivers have for processing two or more simultaneous sources of information? Polytonality was also chosen as the focus because it is an extension of tonal organization, for which empirical methods have been developed. The methods

Reprint requests may be addressed to either author at the Department of Psychology, Uris Hall, Cornell University, Ithaca, New York 14853.
used here have proved useful in the context of tonal music and can be modified to explore the perception of polytonality. Methodologically, however, this study represents a departure from most previous work: it employs a particular musical excerpt rather than abstracted materials such as melodies and chord sequences chosen to be representative of a musical style.

Polytonality is defined by the *Harvard Dictionary of Music* (Apel, 1972) as “the simultaneous use of two (occasionally three or four) different keys in different parts of the musical fabric”; when only two keys are employed the term “bitonality” may be used. Although there are historical precedents, this compositional device was first extensively employed in the early part of the twentieth century. It is seen in compositions by many composers, including Debussy, Ravel, Poulenc, Bartok, Shostakovich, Stravinsky, Ives, Copland, and especially Milhaud. The objective of polytonality is to create the impression of more than one key at the same time, described by Piston (1978, p. 501) as a kind of counterpoint of keys. This counterpoint will be facilitated if the materials are distinguished in terms of timbre, pitch range, dynamics, and rhythm, and if a single tonality is established before others are introduced. Also, two keys may be more easily separated if they are distantly related on the circle of fifths. The tritone, the maximal distance on the circle of fifths, is considered a prime polytonal relationship because it is the “most resonant” of the dissonant combinations of keys (Persichetti, 1961, p. 257) and because these keys have the fewest tones in common (Piston, 1933, p. 50).

Among theorists, historians, and other writers various opinions exist as to the perceptual effects of polytonal organization. They also note the variety of polytonal techniques. Siegmeister (1966, p. 405) finds compositions variously using massive chord blocks and thin contrapuntal lines, in harshly dissonant combinations and delicate textures, and the blending of distant or closely related keys. More than two keys are sometimes used, although this practice has, according to Siegmeister, proven less satisfactory than using two keys. Piston (1933, p. 50) argues more forcefully, saying that two keys can be heard, but using more defeats its own end and destroys the feeling of any tonality; thus, he sets the limit at two keys. He goes on to say that even with just two keys, a delicate adjustment must be made to prevent one tonality from absorbing the other.

Grout (1960, p. 702), in reference to a bitonal passage from the first movement of Milhaud’s Fourth Symphony, claims “... no listener hears the two tonalities B major and G major... What he hears is a G major with a few dissonant notes...” The other elements are considered to be passing tones or other dissonant harmonies. According to this view, one tonality predominates and the other pitch events are heard in (dissonant) relation to it. This claim receives further support from Milhaud, whom Grout quotes as saying the best use of polychords is “only in support of a diatonic mel-
ody.” And, in a similar vein, Persichetti (1961, p. 255) notes that “although each tonal plane has its own organizational center, a single over-all tonic structure is usually felt from the bass.” Salzman (1967, p. 64), in describing Milhaud’s polytonal compositions, concludes that “…the derivation and perceptibility of harmonic structures made out of interlocking or juxtaposed triads may be unquestionable, but long strings of these ‘polychords’ cannot meaningfully establish simultaneous, contradictory tonal centers.” In fact, he takes the whole concept of polytonality to be self-contradictory.

Grout (1960, p. 627) emphasizes that the question is really one of perception: “Of course we can say that polytonality is the property of music written in two or more keys at once. But is it really possible to hear more than one tonality at a time? If it is not, we must conclude that ‘polytonal’ music means no more than music in which one can discern by analysis (usually visual) that two or more lines of melody or planes of harmony, each in a distinct and different key, are sounding simultaneously” (emphasis in original). We investigated this question using one of the most striking and well-known examples of bitonality from Stravinsky’s Petrushka, which was first performed in 1911.

The passage, shown in Figure 1, presents what has come to be known as the “Petrushka chord.” The passage consists primarily of arpeggiated C and F# major chords played first by the first and second clarinets and then by the piano. The C chord is sounded in root position and the F# chord in first inversion. The two chords are presented in the same pitch range and with the same rhythmic patterns and contour. The Petrushka chord (the two-chord simultaneity) is employed in various forms in the piece after being introduced at the beginning of the second tableau. The piano part of the second tableau is based largely on it, with one hand playing the white keys and the other the black keys. Indeed, the organization of the keys on the piano keyboard may have initially suggested the musical materials to Stravinsky (Vlad, 1960/1978). The chord reappears throughout the next two tableaux and its influence is felt until the very end of the piece where the penultimate tone is C and the final tone F# (Hamm, 1967).

This musical passage was selected for a variety of reasons deriving from both perceptual and music-theoretic considerations. Often, it has been considered bitonal with two tonal centers from the maximally distant keys of C and F# major. Each triad in isolation suggests a major key and there is no single major key in which both chords function, supporting the idea that two tonalities, rather than one, are operative. Indeed, this is how the passage was described by Stravinsky himself: “I had conceived of the music in the two keys in the second tableau . . .” (Stravinsky & Craft, 1962, p. 56).

More recently, however, this bitonal interpretation has been questioned. Forte (1955, p. 136–137) asserts that the very notion of bitonality is a logical contradiction and describes the passage as derived by direct linear mo-
tion from the tones C and F#. More recently, the Petrushka chord is seen as having strong commonalities with much of Stravinsky’s other music and is analyzed with reference to the octatonic collection (Berger, 1968; Van den Toorn, 1975, 1977, 1983; Vlad, 1960/1978; White, 1966). The octatonic

**SECTION ONE**

\[
\begin{array}{c}
\text{C} \\
\text{F#}
\end{array}
\]

**SECTION TWO**

\[
\begin{array}{c}
\text{C} \\
\text{F#}
\end{array}
\]

Fig. 1. The passage from Stravinsky’s *Petrushka* indicating the C major voice (top stave) and the F# major voice (lower stave). Sections 1 and 2 were used in Experiment 1; Section 1 only was used in Experiments 2, 3, and 4.
collection, whose description is deferred until later, consists of eight pitches that include the C and F# major chords.

Psychologically, the passage raises a number of interesting questions concerning the perception of pitch organization in music. Do listeners trained in traditional tonal-harmonic music perceive the passage in reference to the two implied tonalities, C and F# major? If so, do they recognize two separate, independent tonalities, or some complex fusion of two keys? How do the perceptual effects change with experience with this particular piece of music? More generally, what are the perceptual capacities for perceiving multiple, simultaneous tonal organizations? To explore these questions, a previously introduced method, the probe-tone technique (Krumhansl & Shepard, 1979) is employed. Earlier studies (summarized in Krumhansl, 1983) using this method have shown that unambiguous key-defining contexts establish a hierarchy on the set of musical tones, which has a variety of consequences for perceptual encoding and memory.

The term “tonal hierarchy” was used to designate the perceptual judgments of how well each tone of the chromatic scale fit with key-defining contexts (Krumhansl & Shepard, 1979; Krumhansl & Kessler, 1982). In those studies, a scale, tonic triad, or chord cadence in a major or minor key was followed by a single pitch, the probe tone, and listeners rated the degree to which the probe tone fit with or followed the context in a musical sense. The ratings conformed to music-theoretic predictions concerning the relative structural significance or stability of the tones; the tonic of the context key received the highest rating, followed by the third and fifth scale degrees, then the other tones of the scale, and finally the nonscale tones.

The initial studies employed simple musical units as contexts to obtain a rating profile characteristic of unambiguously established keys. However, the same methodology can be employed with more complex musical contexts. Krumhansl and Kessler (1982), for example, applied the method to modulating chord sequences to trace how the sense of key develops and changes over time, and Castellano, Bharucha, and Krumhansl (1984) and Kessler, Hansen, and Shepard (1984) used it to investigate the tonal hierarchies in North Indian and Balinese music, respectively, using melodic segments as contexts.

The same technique is applied here to the passage from *Petroushka*, and the results are analyzed to determine whether the ratings can be accounted for in terms of the tonal hierarchies of the two component keys. Then, drawing on techniques for investigating divided and selective attention, the perceptual separability of the two keys is assessed and the results are considered in light of various grouping principles known to operate in music and auditory perception more generally. Finally, the perceptual effects of the octatonic scale are investigated, and the results used to determine the efficacy of this alternative theoretical construct. Thus, this article is a case
study in which perceptual data are brought to bear on a music-theoretic issue arising from the analysis of Stravinsky’s music. The listeners who participated in all the experiments had musical training, but a group of listeners is included that had extensive experience with this particular piece.

Experiment 1

In this experiment, the probe-tone technique is used in conjunction with the musical passage from Petrushka. The passage is heard with the single key voices presented both separately and simultaneously. The single-voice conditions are included to insure that they unambiguously define the expected keys; the ratings from Krumhansl and Kessler (1982), which will be called key “profiles,” are used as the standard of comparison. The condition in which the C and F# major voices are sounded together assesses the listeners’ perception of the relative stability or priority of the chromatic scale tones when the materials from both keys are heard simultaneously.

An analytic technique, multiple regression, is applied to the ratings for the combined C and F# major context. A number of logical outcomes are possible, each of which can be evaluated by multiple regression. First, the combined C and F# context may produce results that cannot be accounted for in terms of the component keys. If the combination of the two arpeggiated triads eliminates any sense of tonal center or centers, or establishes another qualitatively different kind of pitch structure, then we would obtain a low multiple correlation between the combined C and F# context ratings and the standard C and F# major profiles. A second possibility is that listeners assimilate the passage to one key to the exclusion of the other, which would be reflected in a large regression weight for one key and a small regression weight for the other. Individuals may differ as to which key predominates, so it will be necessary to analyze the data for individual listeners separately. Finally, the ratings for the combined C and F# context may reflect a balance between the two component keys. This possibility would be supported by a high multiple correlation and approximately equal weights for the C and F# major profiles.

Method

Subjects

Sixteen adult subjects were recruited from the Cornell University community, and were paid $4.00 for participating in a single experimental session lasting approximately 1 1/2 hr. Listeners were required to have a minimum of 5 years of musical instruction. On average, they had taken music lessons for 9.7 years, had participated in performing groups for 9 years, and were currently spending 6.1 hr/week in musical activities and listening to music for 23.0 hr/week. Four of the listeners had studied music theory at the college level, and three additional listeners had some training in music theory before college. None reported recog-
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nizing the passage used in the experiment or having analyzed it in a music course. All listeners reported normal hearing, and none absolute pitch. Six additional listeners participated in the experiment, but their results were not included in the summary analysis for reasons described below.

Materials

All stimuli were generated by a DMX-1000 digital music synthesizer (Digital Music Systems) under the control of a PDP 11/24 computer (Digital Equipment Corporation). Signals were filtered through an Ithaco Electronic Filter with cutoff set at 3 kHz and amplified by a Dynaco stereo amplifier. The listeners, who were seated in an IAC (Industrial Acoustics Company) sound-attenuated chamber, heard the stimuli on an Ampex AA-620 loudspeaker at a comfortable loudness (~70 dBA).

Each trial began with the passage from Stravinsky's Petroushka, second tableau (rehearsal number 49), which is shown in Figure 1. The passage was divided into two sections, the first extending from measure 9 to 15 and the second extending from measure 16 to 20. In the combined C and F♯ major conditions, the two voices (the C and F♯ melodic lines) were sounded simultaneously. In the single-voice conditions, only the melodic line in C or the melodic line in F♯ was sounded. All together there were six blocks of trials: combined C and F♯ major (Section 1), combined C and F♯ major (Sections 1 and 2), C major (Section 1), F♯ major (Section 1), C major (Sections 1 and 2), and F♯ major (Sections 1 and 2).

The tones used for these passages consisted of five harmonics with relative amplitudes: one, one-half, one-third, one-fourth, and one-fifth; as such, they approximated a sawtooth waveform. There was a linear rise time of 50 msec to maximum amplitude, followed by a linear decrease to zero amplitude over the remainder of the tone duration. The tempo was 50 quarter-tone beats/min, or 1.2 sec/beat. All tone frequencies were based on equal-tempered tuning.

Each passage was followed by a single probe tone drawn from the chromatic scale (C, C♯, D, . . . , B). The probe tone consisted of five sinusoidal components at octave intervals, sounded over the five octaves ranging from C₂ (65 Hz) to B₆ (1975 Hz). The amplitudes of the components were determined by a loudness envelope consisting of three parts: a gradually increasing level over the lowest octave and a half, a constant level over the middle two octaves, and a symmetrically decreasing level over the highest octave and a half. This method, similar to that used by Shepard (1964), produces a tone that has an organlike quality with no well-defined highest or lowest pitch. The probe tones had linear rise and decay amplitude functions over the first and last 100 msec of their durations. Each probe tone began on what would be the first beat of the measure following the passage, and sounded for two quarter-tone beats (2.4 sec). A 5-sec interval between trials allowed the listeners to record their responses. Six different random orders of probe tones were used for the six different blocks of trials.

Procedure

Listeners were instructed to rate how well the probe tone fit with the preceding passage in a musical sense. A rating scale from one (“fits poorly”) to seven (“fits well”) was used for this purpose. Listeners were instructed to try to use the entire range of the response scale. There were four practice trials before the experimental trials; in addition, each block of experimental trials began with two additional practice trials. Half the listeners heard the combined C and F♯ major conditions first, followed by the separate C and F♯ major conditions. The remaining subjects heard the C and F♯ major conditions first, followed by the combined C and F♯ major conditions. This experimental manipulation was included to assess the effect of hearing the components separately on subsequent judgments of the combined passage. The Section 1 trials always preceded the Sections 1 and 2 trials. The order of C and F♯ major conditions was counterbalanced across subjects. Listeners completed a short questionnaire about their musical training and familiarity with the particular passage used in the experiment.
Results

C and F# Major Single-Voice Conditions

The ratings given each of the 12 probe tones for the C and F# major conditions are shown in Figures 2 and 3, respectively. These are averaged over the Section 1 and Sections 1 and 2 trials because the ratings were similar for the 16 listeners. (Five additional listeners were excluded from the analysis because their data exhibited distinctly different patterns for the Section 1 and Sections 1 and 2 trials). The dashed lines in these two figures show the C and F# major key profiles from the earlier experiment (Krumhansl & Kessler, 1982). As can be seen, there is good agreement between the profiles and the ratings for the single key contexts of this experiment. The correlation was .88 for the C major passage and .94 for the F# major passage, both significant at p < .01. These correlations indicate that the single key conditions were heard quite strongly in the expected keys; the F# major key was heard slightly more strongly than the C major key. The correlations with the C and F# major profiles were generally high when the data for the 16 subjects were analyzed individually (although for one additional subject this was not the case and that subject was eliminated for this reason). The results showed no consistent effects of whether the single key conditions were heard before or after the bitonal conditions.

Fig. 2. The probe-tone ratings for the C major voice (dashed line) superimposed on the C major key profile (solid line) from Krumhansl and Kessler (1982).
Fig. 3. The probe-tone ratings for the F# major voice (dashed line) superimposed on the F# major key profile (solid line) from Krumhansl and Kessler (1982).

**Combined C and F# Major Conditions**

The ratings for the probe tones following the combined C and F# major passage are shown in Figure 4; these are averaged across the Section 1 and Sections 1 and 2 trials. To test whether these ratings were a combination of those for C and F# major, a multiple correlation was computed using the C and F# major key profiles. The multiple correlation for the average group data was .80, *p* < .01, with both C and F# profiles contributing significantly. Somewhat greater weight tended to be given to F# major than to C major, but this difference was significant only for those listeners hearing the combined C and F# major conditions before the single key conditions. The values predicted by the regression equation are shown as dashed lines in Figure 4.

The multiple correlation analysis of the group data indicated that the combined C and F# major passage gave rise to probe-tone ratings that are an additive combination of C and F# major key profiles. However, this same pattern would result if some listeners were emphasizing one key while other listeners were emphasizing the other key. In order to test this, the regression analysis was done for individual subjects to determine the regression weights of the C and F# profiles. These weights are plotted in Figure 5, where the horizontal axis corresponds to the weight for the C major key profile and the vertical axis to the weight for the F# major key profile.
Fig. 4. The probe-tone ratings for the combined C and F# major voices (dashed line); the solid line shows the predictions of the regression equation using the C and F# major key profiles from Krumhansl and Kessler (1982).

Fig. 5. The weights for the C and F# major key profiles (Krumhansl & Kessler, 1982) from the multiple regression analysis of the probe-tone ratings for the combined C and F# major voices for individual listeners in Experiment 1.

No evidence exists for a trade-off between C and F# major. If there were such a trade-off, there would be a negative relationship between the weights for C and F# major, that is, the points would tend to fall on a negatively sloping line. In fact, the opposite pattern was found; listeners who had relatively large weights for one key also tended to have relatively large weights for the other key. Thus, the fit of the combined C and F# major data by the
profiles of the two component keys cannot be explained as a consequence of averaging over subjects, some of whom are predominantly hearing C major and others hearing F# major. It can be concluded that the ratings for the combined C and F# major passage are quite well explained as a combination of C and F# major key profiles.

Discussion

The central finding of the first experiment was that the probe-tone ratings for the combined C and F# major context could be described as an additive combination of the rating profiles for unambiguous C and F# major key contexts. The ratings for this passage exhibited less variation than ratings for other, more clearly defined tonal contexts, indicating the hierarchy is less differentiated. But, the results were sufficiently regular so that they could be decomposed into component C and F# major key profiles. For the average data, the value of the multiple correlation was high and both C and F# major profiles contributed to the fit of the multiple regression equation.

An analysis of the data for individual listeners showed that this finding was not a result of averaging across listeners, some of whom heard C major predominantly and others F# major. There was no evidence for a trade-off of this sort between the two keys. Instead, listeners who tended to weight one key heavily also tended to weight the other key heavily. This suggests that in order to perceive one component key it is necessary to hear the other key also. When the C and F# major voices were sounded separately, the ratings strongly resembled those for unambiguous C and F# major contexts from previous experiments. There was little effect of whether the single-voice conditions were heard before or after the combined C and F# major conditions. Together these results indicate that one viable account of this passage is as bitonal, with both component keys perceptually functional. These data will be considered later when we evaluate an alternative account of the passage in terms of the octatonic collection.

Experiment 2

The second experiment further investigated the nature of the hierarchy that the combined C and F# major context establishes on the set of chromatic scale tones. The first experiment indicated that both C and F# major tonal hierarchies are operative, at least for some listeners. This conclusion raises the question of whether the two keys are perceptually separate. That is, do they exist independently on two different planes or are they fused into one complex aggregation of two keys? In order for the perceptual experience to be characterized as truly bitonal, it would seem necessary to demon-
strate that listeners hear the two tonalities on separate planes, each with the full range of perceptual effects deriving from tonal organization. This would include melodic, harmonic, and key relations known to affect encoding and remembering of tonal music (see Krumhansl, 1983, for a summary of some empirical findings). A first step toward investigating this question is determining whether the keys are, in fact, perceptually separate.

The methodology used in this experiment is patterned after investigations of divided attention in the information processing literature. In the divided attention situation, subjects are required to attend to two or more different channels of information and be prepared to make responses to signals in all channels. The effect of dividing attention between channels is typically to decrease performance levels compared to the single-channel situation, leading to conclusions concerning limited attentional resources. The magnitude of the performance decrement depends on the amount of stimulus interference and response incompatibility. Practice has in some cases been shown to greatly enhance performance in divided attention tasks (e.g., Spelke, Hirst, & Neisser, 1976; Hirst, Spelke, Reaves, Cahanack, & Neisser, 1980). This vast literature will not be reviewed here; the critical feature for our purpose is that in the divided attention situation subjects are required to attend to information presented in more than one channel simultaneously.

In this experiment, we use dichotic presentation which is the classic method used in the attention literature (e.g., Cherry, 1953; Broadbent, 1954; Treisman, 1960). The C major voice is sounded in one ear through headphones and the F# major voice is sounded simultaneously in the other ear. Only one of these channels will be relevant for the probe-tone judgment, but its identity is not known until the probe tone is presented. After the C and F# major voices are presented dichotically, the probe tone is sounded in one ear only, signaling the voice with respect to which the probe-tone judgment is to be made. This requires listeners to attend to both channels of input simultaneously. If listeners encode the two voices separately, then the cue (the probe tone signaling the relevant voice) should allow the listeners to base their rating on the tonality of the cued ear. That is, in the multiple regression of the ratings, the weight of a tonality should be larger when it is heard in the cued ear than when it is heard in the uncued ear.

Method

Subjects

Nine adult listeners were paid $3.00 for participating in an experimental session lasting approximately 45 min. On average, they had 11.2 years of experience playing an instrument or singing, practiced 4.8 hr/week, and listened to music for 13.0 hr/week. Additionally, half
of the listeners reported that they currently performed music regularly, and two-thirds had some music theory training. No listener reported prior familiarity with the musical passage used in the experiment.

Materials

All stimuli were produced by a DMX-1000 digital music synthesizer under the control of a PDP 11/23 + computer. Signals were input to a NAD 3125 stereo amplifier and were presented to subjects over Telephonics TDH-39 headphones at a comfortable listening level. Each tone had a complex harmonic structure, with five overtones above the fundamental. A 10-msec linear rise time in amplitude was followed by a linear decay to zero amplitude over the remaining duration of the tone.

Each trial began with the first five measures of Section 1 of the combined C and F♯ major passage from Stravinsky’s Petrushka (see Figure 1), with the G♯ to F♯ figure that accompanies the F♯ major melodic line omitted. This passage was presented dichotically, with the C major melodic line in one ear and the F♯ major melodic line in the other. There were two blocks of trials during which listeners heard the C voice in their right ear (and F♯ in their left) and two during which the C voice was heard in their left ear (and F♯ in their right). After a 2-sec interval, a probe tone was sounded monaurally, either to the left or right ear. The ear in which the probe tone was sounded varied from trial to trial. All possible combinations of probe tone, ear of probe tone, and ear of C and F♯ melodic lines were included in the experiment.

Procedure

Listeners were instructed to rate, using the same response scale as Experiment 1, how well the probe tone fit with the tonality of the voice that was sounded in the same ear as the probe tone. Thus, the appearance of the probe tone in one ear was the cue designating the melodic line on which listeners were to base their response. Because the cue occurs after the context, it is called a postcue. After a short series of practice trials, listeners heard the blocks of trials in different random orders.

Results

Because the ear of the probe-tone cue (left vs. right) had little effect on the results, these data were averaged producing two conditions: the C cue condition (in which the melodic line in C major was in the same ear as the probe tone) and the F♯ cue condition (in which the melodic line in F♯ major was in the same ear as the probe tone). To assess whether the cue resulted in greater weight being given to the cued melodic line, multiple regression analyses were performed on the data for the individual subjects. The top of Figure 6 shows the regression weights for C and F♯ major profiles (Krumhansl & Kessler, 1982) for the C cue condition and for the F♯ cue condition. If listeners are able to use the cue effectively, the open circles (for F♯ major cue) should be located upward and to the left of the filled circles (for C major cue). This pattern was not found, indicating that the listeners were unable to base their responses on the cued melodic line. In general, listeners’ ratings reflected a weighted combination of both C and F♯ major, with a multiple correlation between the average data and the C and F♯ major profiles of .71, p < .05.
Fig. 6. The weights for the C and F# major key profiles (Krumhansl & Kessler, 1982) from the multiple regression analysis of the probe-tone ratings for the combined C and F# major voices from Experiment 3 (top graph) and Experiment 4 (lower graph). The conditions in which the C major voice was cued are shown as filled circles; the conditions in which the F# major voice was cued are shown as open circles.

Discussion

The results of this experiment can be summarized very simply. Listeners were unable to use the postcue effectively to base their responses on the voice sounded in the cued ear. That is, the weight in the multiple regression for each key was no greater when the corresponding voice was sounded in the cued ear than when it was sounded in the other ear. Otherwise, the
results replicated those of the first experiment, with the combined C and F# major passage showing influences of both keys with approximately equal weights and no trade-off between the two keys across individual listeners.

The failure of the postcue may be interpreted in a variety of ways. It may be that the ear-of-input is simply not encoded by the perceptual system. This possibility, however, can be ruled out by the large number of studies showing that dichotic localization of sound sources is a highly effective cue for selective listening (see, c.g., Broadbent, 1954). A second possibility is that the probe-tone task is poorly suited to the divided attention situation. Because the probe tone is presented some time after the context, which itself is extended in time, the task requires that the passage and its ear of input be remembered until the probe tone is sounded. This memory load may be responsible for the ineffectiveness of the postcue, leaving open the question of whether the two keys are perceptually separable. This possibility is investigated directly in the next experiment. Finally, the two component tonalities may in fact not be perceptually independent, preventing the listener from weighting one key more heavily than the other.

**Experiment 3**

This experiment investigated the possibility that the postcue in the previous experiment was ineffective for focusing attention on one of the component keys because of the memory demands of the experimental task. The present experiment used a variant of the earlier task designed to reduce the memory load to a minimum. Specifically, the C and F# major components were again presented dichotically, but listeners were told in advance which ear would receive the passage on which the probe-tone judgment was to be based. If this cue is effective, then the responses should look like the responses for the single voice conditions for the voice sounded in the cued ear. That is, there should be large weights in the regression analysis for the key of the cued voice and low weights for the uncued voice.

This task was patterned after the classic selective listening experiments (Cherry, 1953; Broadbent, 1954; Treisman, 1960; Deutsch & Deutsch, 1963). In these, subjects are instructed to listen to one of two simultaneous messages presented dichotically. These studies usually use verbal materials, and subjects are required to “shadow,” that is, repeat, the message in the designated ear. Under these circumstances, listeners typically could perform the shadowing task well but could report very little about the nature of the message in the unattended ear. Their reports were limited to such features as whether the unattended message was a human voice or a noise, whether it contained a gross change in pitch or loudness, and whether the speaker was male or female. Treisman (1960) and others, however, showed that subjects did process the meaning of the unattended message to some
degree if, for example, it contained a very important word or continued the meaning of the attended message, but that in general the unattended message was highly "attenuated." These earlier studies suggest that the precue in the present experiment should enable listeners selectively to base their probe-tone ratings on the tonality presented in the designated ear and filter out the passage in the other ear.

**Method**

**Subjects**

Eleven adult listeners were paid $3.00 for participating in an experimental session lasting approximately 45 min. On average, they had 10.4 years of musical experience, practiced 4.7 hr/week, and listened to music 23.1 hr/week. Four of the eleven had some music theory training, and one reported having absolute pitch. No listener reported prior familiarity with the musical passage used in the experiment.

**Materials**

The stimuli were generated in the same manner as those in Experiment 2, except that a StereoScope amplifier and Sharpe Pro-66 headphones were used. The passage was identical to that in Experiment 2. However, the probe tone was presented binaurally (to both ears simultaneously) and the ear in which the C and F# voices were presented was intermixed within blocks of trials.

**Procedure**

Before the start of each block of trials, listeners were told to attend to the melodic line in either the left or the right ear throughout the block of trials. They were instructed to rate how well the probe tone fit with the tonality of the voice in the designated ear. Because the cue occurs before the trials, it is called a precue. After a series of practice trials, listeners heard the blocks of trials in different random orders.

**Results**

The designated ear (left vs. right) had little effect on the results, so these data were averaged producing two conditions: the C cue condition (in which the melodic line in C major was in the designated ear), and the F# cue condition (in which the melodic line in F# major was in the designated ear). To assess whether the cues resulted in greater weight being given to the cued melodic line, multiple regression analyses were performed on the data for the individual subjects. The bottom of Figure 6 shows the regression weights for C and F# major profiles for the C cue condition and the F# cue condition. Again, if the cue is effective, then the open circles should be located upward and to the left of the filled circles. This pattern was not found, indicating that cueing for one melodic line did not selectively increase its weight. In general, the ratings showed influences of both C and F# major,
with a multiple correlation between the average data and the C and F# major key profiles of .73, \( p < .05 \).

**Discussion**

In this third experiment, the precue was found to be as ineffective as the postcue of the second experiment. That is, even though listeners in this experiment knew in advance of the trials which ear would receive the relevant passage, the tonality of that passage received no greater weight than the tonality of the passage in the unattended ear. Thus, the second experiment’s finding that a postcue was ineffective cannot be attributed to the memory demands of that task. It would seem, then, that the two tonal hierarchies, although both apparently operative, are not perceptually separate. Instead, it appears that the passage gives rise to a complex fusion of two keys that cannot be separated, at least by the dichotic presentation of the second and third experiments.

Although unlikely, given the extensive literature on selective listening with verbal materials, it may be that listeners have difficulty localizing the two voices when presented through earphones. To explore this possibility, another experiment was conducted informally in which the two passages were presented over spatially separated loudspeakers. This manipulation also proved ineffective for perceptually separating the voices in C and F# major. Another informal experiment played the two components in different timbres and this manipulation, like the others, failed to separate the two voices. It appears, then, that the fusion of the components is quite a robust phenomenon. Possible reasons for this outcome, and the differences between the present findings and those in the selective listening literature, will be discussed following the next experiment, which is a replication of the first three using a group of listeners who are very familiar with this particular piece of music.

**Experiment 4**

In the first three experiments, all listeners were trained in music but they were previously unfamiliar with the musical passage used in the experiments. To assess the effect of familiarity, the present experiment employed as listeners members of the Cornell University Orchestra, which had recently performed the piece. This group included the two clarinetists and the pianist who had played the arpeggiated C and F# major triads at the beginning of the second tableau (Figure 1). Otherwise, the listeners were approximately matched in terms of musical background to those in the previous experiments. Of interest was whether the experienced listeners would pro-
duce a different pattern of results. In particular, did the component keys operate more or less strongly and were they more or less perceptually separate for these listeners than for those unfamiliar with the piece? In order to make the relevant comparisons, the experiment included trials patterned after those in the first three experiments; this necessitated a reduction in the number of trials of each type but each different trial type was represented, giving complete replications of the previous experiments.

Method

Subjects

Ten adult listeners were paid $4.00 for participating in the experiment that lasted approximately 1 hr. They were recruited from the Cornell University Orchestra, which had recently performed Stravinsky's Petrouchka in concert. On average, they had 9.45 years of lessons on an instrument, practiced for 8.5 hr/week, and listened to music 20.3 hr/week. Seven had studied music theory, and none reported absolute pitch. All were familiar with the musical passage used in the experiment.

Materials

The stimuli were generated using the same equipment as in Experiment 3. Because this study was meant to be a miniature replication of the previous three experiments, the stimulus materials were patterned after them with the following changes. For the replication of Experiment 1, the passage used was the simplified version of Section 1 (used in Experiments 2 and 3). The stimuli were presented binaurally, and the probe tones had the same harmonic content as the tones in the passage. The replication did not include the C and F# major single-voice conditions. The replications of Experiments 2 and 3 used the same materials as before, except that only half as many trials were included. All possible combinations of probe tones, ear of cue, and ear of C and F# major voices were represented, however. There was an additional part of the experiment in which each trial began with an octatonic scale beginning on C or F#, but the discussion of the results will be deferred until later.

Procedure

The instructions to the listeners were the same as in the previous experiments. All listeners heard the blocks of experimental trials in the following order: combined C and F# major passage (no cue), combined C and F# major passage (postcue), combined C and F# major passage (precue) and, finally, the octatonic context (described later).

Results

The results for the listeners experienced with the musical selection largely confirmed those of the first three experiments. Correlations between the results in the first three experiments and the corresponding conditions of this experiment averaged .81 and were individually significant. The statistical reliability of the data from this experiment, however, was weaker owing to the reduced number of trials in each condition. The probe-tone ratings following the combined C and F# major passage (no cue)
showed some influence of both C and F♯ major profiles, with a multiple correlation of .54, \( p = .21 \). Again, there was no evidence that individual listeners selectively heard one key over the other. The postcue and precue conditions also showed combined influences of C and F♯ major, with multiple correlations of .61, \( p = .11 \), and .62, \( p = .10 \), respectively. But, as before, neither kind of cue was effective in producing a greater weight for the key indicated by the cue.

**Discussion**

This experiment largely replicated the findings of the first three experiments, so it would be well to summarize the results to this point before turning to the final experiment, which addresses a somewhat different issue. The four experiments applied the probe-tone technique to a passage from Stravinsky's *Petroushka* which simultaneously presents two arpeggiated C and F♯ major triads. In all experiments, the probe-tone ratings could be decomposed using multiple regression into the C and F♯ major key profiles. That is, the ratings could be explained as a linear combination of the ratings of probe tones following unambiguous C and F♯ major contexts. In all experiments, the two keys had approximately equal weights and there was no evidence for a trade-off between the two component keys across different listeners.

Attempts to induce differential weightings of the two keys by presenting the C and F♯ major voices to different ears proved consistently futile. This was true even when listeners knew in advance of the trials which ear would receive the passage on which the probe-tone rating was to be based. The pattern of results did not depend on whether the listeners were familiar with the piece prior to the experiment. Thus, the findings so far suggest that the best description of this passage from a perceptual point of view is as the complex fusion of the two keys of C and F♯ major.

What characteristics of the musical passage might promote the apparent fusion of the two voices? To answer this question, one must consider the passage in light of the research on auditory stream segregation. Empirical studies have identified various factors that promote the perceptual segregation of a sequence of sounds into independent organizations; other factors tend to promote fusion. Referring back to Figure 1, and especially Section 1 which was used in all four experiments, it can be seen that the two arpeggiated triads in C and F♯ major are presented in a highly parallel fashion. The rhythmic pattern of the two voices is identical, as is the contour (the pattern of rising and falling pitches). Moreover, the two voices are close in pitch, with a distance that never exceeds three semitones. (The pitch separation in Section 2 is somewhat greater with values of from six to eight semitones.)
The literature suggests that these are precisely the conditions that lead to perceptual fusion. A number of studies (Bregman & Campbell, 1971; Bregman & Pinker, 1978; Dowling, 1973; Miller & Heise, 1950; Van Noorden, 1975) have demonstrated that tones tend to belong to the same perceptual stream when their pitch difference is small. Simultaneity of onset (and offset) is another factor that has been shown to promote fusion (Dannenbring & Bregman, 1978; Bregman & Pinker, 1978; Rasch, 1978). Both these factors, pitch proximity and temporal synchrony, have been shown to override information about the location of the sound sources. Deutsch (1975) described an illusion in which scale tones were presented to the two ears alternately, but most listeners incorrectly heard tones close in frequency as emanating from the same side. The results of Warren and Bashford (1976) and Steiger and Bregman (1982a, b) suggest that synchrony of sounds in different ears can cause dichotically presented sounds to fuse.

In the musical passage we examined, the factors of pitch proximity and temporal synchrony combine to promote the fusion of the C and F♯ major triad components. Moreover, these factors would tend to override information about the location of the two voices when presented dichotically and prevent listeners from selectively attending to one or the other voice. The similarity of contour of the two voices may also be a contributing factor. Although contour per se has not been examined directly in the stream segregation literature, it may have been a factor contributing to Deutsch’s (1975) scale illusion. Also, Steiger and Bregman (1981) noted that two pitches gliding in parallel tend to fuse into a single tone. This literature may also suggest why the results from the present experiments differ from the selective listening studies using verbal materials. In those, the two voices would rarely be so similar in temporal synchrony, pitch, and contour. In the Petrushka passage, however, all three factors appear to operate to fuse solidly the C and F♯ major voices in perception.

Experiment 5

This last experiment was conducted in order to assess the octatonic collection as an alternative account of the Petrushka passage. According to Van den Toorn (1983), Messiaen (1944) was the first to relate Stravinsky’s music to the octatonic collection. Brief mention of this connection was also made by Vlad (1960/1978) and White (1966) with reference to only a few of his works. Berger (1968) provided the first systematic analysis of Stravinsky’s music in terms of the octatonic collection. That article served as the basis for Van den Toorn’s (1975, 1977) initial studies on the topic, which were subsequently (1983) expanded into an extremely comprehensive and detailed account of octatonic, diatonic, and mixed octatonic—
diatonic pitch structures in Stravinsky's music from *The Firebird* on.

The employment of the octatonic set in Stravinsky's compositions can be traced to Rimsky-Korsakov and can be seen to be operative in Stravinsky's early music. But, according to Van den Toorn (1983, p. 23), "... what dramatically distinguishes the invention in *Petroushka* from these earlier examples is the superimposing of these tritone related (major) triads... They are now imposed simultaneously. And the 'bite' of this invention, from which the most startling implications were to accrue in pitch organization (and, as a consequence, in melodic, formal, instrumental, and rhythmic design as well) opens up a new universe, a new dimension in octatonic thought, one that Stravinsky was to render peculiarly his own" (emphasis in original).

Only a brief and elementary account will be attempted here of the formal characteristics of the octatonic collection, and discussion of its applicability to Stravinsky's music will be limited to the passage under consideration. The octatonic collection consists of eight tones, rather than the seven of the diatonic set. The size of the interval between adjacent tones alternates regularly between one and two semitones. For example, one octatonic collection, shown in Figure 7, consists of the tones: C, C♯, D♯, E, F♯, G, A, and A♯; there is one semitone between C and C♯, two semitones between C♯ and D♯, one semitone between D♯ and E, two semitones between E and F♯, and so on. This pitch collection contains a high degree of symmetry under rotation; when transposed by three, six, or nine semitones the collection is unchanged. This means that there are only three distinct octatonic collections all together, corresponding to the original and transpositions by one and two semitones. Another way of describing the octatonic collection is as the joining of two diminished triads—C E♭ G♭ A and C♯ E G B♭; for this reason jazz musicians refer to it as the "diminished scale."

Van den Toorn (1983) makes a further distinction, however, depending on the position of the tone in the octatonic collection that is assigned priority, referred to by the number zero. If the next tone is one semitone above the tone with priority, it is called Model A; if it is two semitones above, it is called Model B. The arrangement of the tones in Figure 7, with C as the tone of priority, is Model A because the next tone, C♯, is one semitone above C. It is to this octatonic set that the Petroushka chord is related, although it is equivocal whether the tone of priority should be taken to be C or F♯. As Berger (1968) notes, whereas for the (major) diatonic set there is only one possible assignment of priority, for the octatonic set of Figure 7 any of the tones at 0, 3, 6, or 9 has the "potentiality of being the pitch class of priority... there are, loosely speaking, four potential 'tone centers' of equal weight and importance" (p. 133). The determination of priority depends on the explicit emphasis given the tones in the music, and for the passage under consideration, C and F♯ are the strongest candidates. Either choice, it
should be noted, has the potential of establishing the priority of the other.

Van den Toorn (1983) observes that the octatonic collection of Figure 7 (Model A) yields three natural partitions; there are other partitions for Model B which need not concern us here. The Model A partitions are the minor triad on C (pitch classes 0 3 7), the major triad on C (pitch classes 0 4 7), and the dominant seventh on C (pitch classes 0 4 7 10). The same partitions can equally well be built on F#. The Petroushka passage suggests the major triad partitions on C (0 4 7) and F# (6 10 1). He stresses, however, that these major triads are not tonally functional in the traditional sense:

"... to include the 'Petroushka-chord' context... within the tonally functional C-scale compounds of earlier music would be to invite so crippling a degree of qualification so as to render the inclusion nearly incomprehensible" (p. 65). He admits that if the F# A# C# triad were ignored, a "crudely drawn" key of C major is "conceivable," and presumably a F# major key is also conceivable if the C E G triad is ignored. "But the overall effect does not admit such an interpretation. Aside from the inherent contradictions posed by the notion of 'bitonality', a simultaneous unfolding of separate 'tonalities' or 'keys' is not part of our perceptual experience" (p. 65).

Fig. 7. The top figure shows the octatonic scale beginning and ending on C, with the names and pitch class numbers of the tones and intertone intervals indicated. The lower figure shows the probe-tone ratings for the octatonic scale contexts beginning and ending on C (solid line) and F# (dashed line). Open circles indicate tones in the octatonic collection; filled circles indicate tones not in the octatonic collection.
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More specifically, Van den Toorn (1983, p. 53) proposes the following diagram of priorities for this particular passage:

Level 2: 0, 6
Level 3: (0 4 7) on 0, 6
Level 4: (10 1 6) (0 4 7)
Level 5: 0 1 (3) 4 6 7 (9) 10 (0)

At the highest and most significant level are the two tones of primary priority, C and F#. At the next level, the major chord partitions on 0 and 6 are indicated; these are written out at the next lower level in terms of the tones of the two major triads. Then, at the lowest level is the complete octatonic collection in which the 3 and 9 tones are inoperative. As can be seen from the diagram, the tones 0 and 6 appear on all hierarchical levels, whereas the tones 1, 4, 7, and 10 appear only at the three lower levels, and the remaining tones do not appear at any level of the hierarchy. Thus, the diagram can be roughly quantified as follows:

Tone: 0 1 2 3 4 5 6 7 8 9 10 11
(0 4 7) partition 2 0 0 0 1 0 0 1 0 0 0 0
(6 10 1) partition 0 1 0 0 0 0 2 0 0 0 1 0

These two sets of values will be called the theoretical C and F# major partition model which will, as quantified above, be fit to the data from the first four experiments.

Another way of approaching the question of whether the octatonic collection provides a satisfactory account of the results is to obtain some measure of the perceptual effects of the octatonic collection itself. In this experiment, the probe-tone methodology was again employed; each trial began with the octatonic collection played in scalar form. The scale was sounded in either ascending or descending order and, because the tones of C and F# are the most likely tones of priority, the scales began and ended on either C or F#. Figure 7 shows the ascending octatonic scale beginning and ending on C which, for simplicity, will be called the C octatonic scale. The F# octatonic scale contains the same tones but begins and ends on the tone F#.

The probe-tone ratings made for the octatonic scales will be presented and given a cursory analysis here for possible theoretical interest. The main use of the data, however, will be as a way of assessing the octatonic collection as an alternative explanatory construct to the traditional bitonal interpretation of the Petroushka passage. To this end, the probe-tone ratings for the combined C and F# major context of the first four experiments will be analyzed using multiple regression with the octatonic scale ratings from the present experiment as predictors. Because experience with Stravinsky's music, and this piece in particular, may be an important factor, the listeners of the fourth experiment who had recently performed the piece also gave
probe-tone ratings for the octatonic scale contexts, and their results in all conditions are compared to the octatonic scale context ratings of the present experiment.

Method

Subjects

Eight listeners were paid $3.00 for participating in the experiment which lasted approximately one-half hour. On average they had 17.9 years experience playing music, practiced 4.1 hr/week, and listened to music for 12.8 hr/week. Five currently performed music regularly, and half had studied music theory.

Materials

Stimuli were produced using the same apparatus as in the previous experiment, but presented over KLH loudspeakers. Each trial began with an ascending or descending octatonic scale beginning and ending on either C or F#. These tones were 300 msec in duration. The probe tone, with duration of 600 msec, was always sounded in the same octave as the octatonic scale tones with the constraint that the probe tone was never in the same octave as the very last tone of the octatonic scale context.

Procedure

After a block of practice trials, listeners heard four blocks of experimental trials. Within blocks, C and F# octatonic scales were randomly intermixed, but the scales were always either ascending or descending. The order in which the ascending and descending blocks were heard was counterbalanced across listeners. They were told that the scale sounded at the beginning of each trial would be an octatonic scale, which is more complex than a diatonic scale. They were asked to rate how well they felt the probe tone fit with the octatonic scale context.

Results

The results were similar for ascending and descending octatonic scales, so these values were averaged to produce the results shown in Figure 7. However, the C and F# octatonic scale data were different, so these were not averaged. The listeners in Experiment 4, who also gave ratings for the octatonic scale contexts, produced similar results; the average correlation between corresponding octatonic scale conditions in the two experiments was .82, p < .01.

It is clear that the tone with which the scale began and ended had an effect on the ratings; C received the highest rating for the C octatonic scale and F# received the highest rating for the F# octatonic scale. There were a number of other relatively large differences between the two octatonic scale contexts. In particular, the tones F and A received higher ratings for the C octatonic scale than the F# octatonic scale, and the tones B and D# received higher ratings for the F# octatonic scale than the C octatonic scale. These
six tones (C, D#, F, F#, A, and B) accounted for the largest differences between the C and F# octatonic conditions. Note that this set consists of the tones of the F major triad (F, A, C) and the B major triad (B, D#, F#). This is particularly striking because F and B, both of which received relatively high ratings, are not sounded in the octatonic scale context.

In general, tones in the octatonic scale (open circles in Figure 7) did not receive higher ratings than tones not in the octatonic scale (filled circles). The ratings for the C octatonic scale did, however, resemble the C major key profile \(r = .74, p < .01\) and also the F major key profile \(r = .68, p < .05\). The multiple correlation between the C octatonic scale data and the C and F major profiles was .80, \(p < .01\). Similarly, the ratings for the F# octatonic scale resembled the F# major key profile \(r = .69, p < .05\) and also the B major key profile \(r = .67, p < .05\). The multiple correlation between the F# octatonic scale data and the F# and B major profiles was .76, \(p < .05\).

To determine the extent to which the data for the combined C and F# major passage from the four earlier experiments could be accounted for by the C and F# octatonic profiles, a series of multiple regression analyses was performed. These tests looked to see how well the data from no-cue, post-cue, and precue conditions could be predicted by the C and F# octatonic scale profiles. A summary of the results of these tests is contained in the second column of Table 1. For comparison, the multiple correlations for the same sets of data and the C and F# major key profiles are shown in the first column. In no case did the octatonic scale profiles give a significant multiple correlation, and in all cases, the C and F# major key profiles provided a better fit. Similar results were obtained for the data from Experiment 4 when the octatonic scale data from that experiment were used as predictors rather than the octatonic scale data from this experiment.

The data from the four experiments were also tested against the theoretical C and F# major partition model quantified as described earlier. The multiple correlations for these two sets of predicting variables are also shown in the last column of Table 1. As can be seen, the multiple correlations for this theoretical model consistently exceeded those for the other two sets of predictors (the C and F# major key profiles, and the C and F# octatonic ratings). In five cases, the multiple correlation was significant; in the remainder (no cue, Experiment 4) the multiple correlation of .68 closely approached significance \(p = .057\).

**Discussion**

To first summarize the probe-tone ratings for the octatonic scale contexts, there were strong effects of the tone (C or F#) with which the scale began and ended. Thus, different patterns were found depending on which
tone was explicitly given priority. There were significant correlations between the C octatonic data and the C major profile and between the F# octatonic data and the F# major profile. Additionally, the C octatonic context raised the level of the other tones of the F major triad (F and A) over their levels for the F# octatonic context. Note that the octatonic collection contains the tones (C E G B) of the dominant seventh chord of the F major key, and the C octatonic data correlated significantly with the F major key profile. Analogously, the F# octatonic scale context raised the level, not only of the F# tone, but also B and D#, which comprises the B major triad whose dominant seventh (F# A# C# E) is contained in the octatonic collection. And, the F# octatonic data correlated significantly with the B major key profile.

These results may be of interest in light of Van den Toorn’s (1983) partition of the octatonic collection as a dominant seventh (0 4 7 10). However, to account for the elevated ratings of the corresponding tonic triad tones, it would seem necessary to assume that the dominant seventh is tonally functional. There is little evidence to support the perceptual reality of the two other partitions, (0 3 7) and (0 4 7), of the octatonic scale; the tones at 3 and 4 (E and E for C octatonic; A and A# for F# octatonic) received relatively low ratings. Nor is there consistent support for the potential priorities of
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the pitch classes in the relation (0 3 6 9). As already noted, although pitch
class 9 (A for C octatonic; D# for F# octatonic) received relatively high rat-
ings, this was not the case for pitch class 3 (Eb for C octatonic; A for F#
octatonic) or pitch class 6 (F# for C octatonic; C for F# octatonic).

The octatonic context results were similar for listeners regardless of their
prior familiarity with Petrushka. The ratings did not differ between listen-
ers in the fourth experiment, who had recently performed the piece and had
just heard the particular passage repeatedly prior to making the octatonic
scale ratings, and the listeners of the fifth experiment, who were hearing the
cvatonic collection possibly for the first time. These exploratory analyses
suggest the best description of the octatonic collection when presented as an
isolated scale is, from a perceptual point of view, as a tonally functional
dominant seventh chord, although the data of Figure 7 may invite alterna-
tive accounts.

The main objective of the experiment, however, was to test empirically
whether the Petrushka passage is better accounted for in terms of the octa-
tonic scale data or the C and F# major key profiles. The probe-tone ratings
for the combined C and F# major passage were analyzed in terms of three
sets of values: (1) the C and F# octatonic scale ratings of this experiment, (2)
the C and F# major key profiles from Krumhansl and Kessler (1982) and (3)
the quantified theoretical C and F# major partitions from Van den Toorn
(1983, p. 53). This was done separately for the first three experiments and
their replications in the fourth experiment with the experienced listeners.

In no case did the octatonic scale data provide a satisfactory account of
the Petrushka passage; all multiple correlations failed to reach signifi-
cance. The explanatory power of the C and F# major profiles was greater as
evidenced by consistently higher multiple correlations. But, the highest cor-
relations were for the theoretical C and F# major partitions. According to
the theoretical analysis given by Van den Toorn (1983, p. 53) the passage
establishes a hierarchy of priorities in which the C (0) and F# (6) tones domi-
nate, followed by the other tones of the major triad partitions. This hierar-
chy, roughly quantified, provided the best account of the data for the pas-
sage. The advantage of the theoretical partitions over the C and F# major
scale profiles was larger for the experienced listeners than for the others
who were hearing the passage for the first time. This suggests that, through
experience, listeners come to appreciate the hierarchy of priorities articu-
lated by the music and relate the passage less to the diatonic tonal hierar-
chies.

Summary and Conclusions

The five experiments reported here examined the perceptual effects of
the Petrushka passage using the probe-tone (Krumhansl & Shepard,
1979) methodology. The passage has been described in the literature in terms of two alternative theoretical constructs, neither of which received unqualified support. The first of these describes the passage as bitonal in C and F# major keys. Partial support for this view was obtained. First, when the C and F# major voices were played separately, the probe-tone ratings resembled those for unambiguous C and F# major key contexts. Second, the probe-tone ratings made following the combined C and F# major passage could be statistically decomposed into C and F# major tonal hierarchies. Finally, one key did not tend to dominate over the other; instead, there was a fairly equal balance between the two keys. These results suggest that the passage establishes at least some impression of the C and F# major keys standing in the highly dissonant relation of a tritone with approximately equal weights.

The two keys, however, do not appear to exist on separate and independent perceptual planes. Listeners were unable to attend selectively to one of the component keys and ignore the other. This failure suggests that the material is perceptually fused into a complex pitch configuration simultaneously oriented around C and F# major. This fusion likely derives from the highly parallel treatment given the arpeggiated C and F# major triads. The two voices have identical contour and rhythmic patterns and are close in pitch. These factors would promote the fusion of the materials of the two keys even when they are presented dichotically. Thus, the experiments do not demonstrate a capacity to hear two independent tonalities simultaneously, although this result might be obtained with a bitonal passage that differentiates the two components more in terms of pitch, contour, and rhythm.

A second theoretical construct, the octatonic collection, was also tested empirically. The probe-tone ratings made following octatonic scales suggested that this context operates perceptually as a kind of tonally functional dominant seventh chord. The other minor and major triadic subsets were not reflected in the ratings. The main finding was that the octatonic scale profiles did not provide a satisfactory account of the effects of the combined C and F# major passage from Petrushka. The octatonic collection may be inherently difficult for listeners to abstract and remember because of its highly symmetrical nature. Unlike the diatonic collection, its structure suggests multiple tones of priority, rather than a unique focal tone (see Krumhansl, 1986, for other differences between the octatonic and diatonic sets). Although the octatonic collection provides a wealth of compositional resources, as persuasively documented by Van den Toorn (1983), the isolated scale does not fully evoke these possibilities.

The octatonic collection, however, can give rise to different pitch structures depending on how a particular composition emphasizes various tones of the collection. That is, the composition articulates a hierarchy of priori-
ties out of the various possibilities afforded by the collection. Van den Toorn (1983, p. 53) proposes, for the particular passage under consideration, a hierarchy of priorities. This theoretical model provided the most satisfactory account of the perceptual effects of the passage. Support was also obtained for Van den Toorn’s (1983, p. 65) description of the passage as producing a unified, cohesive effect in which the two triadic components assume equal weight and stand in a “fixed, polarized” opposition. The effect has a striking “inert, deadlocked character,” one that from a perceptual point of view derives from auditory grouping processes and the particular articulation by the music of a hierarchy of priorities for the bipolar tones C and F#.

We return, finally, to the question with which we began: can listeners perceive two or more tonal organizations simultaneously? The results for the musical passage investigated here do not convincingly demonstrate this ability. Although some influence of the two component keys is felt, none of the manipulations were effective in separating the keys. It is doubtful, therefore, that the keys are heard as independent, fully functional entities. Various factors, noted above, would tend to fuse the two voices. In addition, it may be difficult for listeners to feel the tendencies of unstable tones to resolve to stable tones in more than one key simultaneously. This may be especially difficult for these two distantly related keys, in which the tendencies would often work in opposition. For example, in C major the tone F# would have a strong tendency toward G, whereas it would be stable in F# major and definitely not have a tendency toward G. The two component keys, instead of establishing separate spheres of influence, appear to join into a single, complex organization.

In closing, some parallels with the psychological representation of polyrhythms are worth noting. The results of Deutsch’s (1983) study, in which subjects were required to tap in synchrony with two simultaneous dichotically presented rhythms, could be accounted for if it is assumed that polyrhythms tend to be cognitively organized according to an underlying metrical system containing both component rhythms. That is, the two rhythms are coded with respect to a single equitemporal pattern of beats some of which are articulated by the individual rhythms. For example, a two-against-three polyrhythm is coded with respect to a cycle of six beats. Indeed, the notion of a regular underlying pulse with respect to which points of stress are coded is central to Povel and Essen’s (1985) more general theory of rhythm. A similar principle may be operating here whereby a simple underlying organization of pitch intervals is formed and used to code the sounded events in terms of the hierarchy of tonal priorities articulated by the music.

However, Handel and Oshinsky (1981), Handel (1984), and Beavillain and Fraisse (1984) have found that under certain circumstances listeners
tend to tap in synchrony to one of two component polyrhythms, with the other component coded in relation to the dominant rhythm. This would be analogous to the case in which one tonality dominates and the elements of the other tonality are heard in (dissonant) relation to it. The conditions under which this outcome is obtained, the possibility that similar organizational principles operate in tonal and rhythmic perception, and the potential for polytonality to affect the perception of polyrhythms and vice versa are intriguing questions for further empirical investigation.¹

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¹ We are greatly indebted to William W. Austin for his advice on theoretical matters, his insights on the experimental tasks, and his encouragement of this study. We would also like to thank the members of the Cornell University Orchestra, under the direction of Edward Murray, for serving as expert subjects. Portions of this study were presented at the meeting of the Psychonomic Society, San Antonio, 1985. The research was supported by a grant from the National Institute of Mental Health (MH39079) to the first author, and a National Research Service Award from the National Institute of Mental Health (MH09248-0151) to the second author.


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