Real-Time Responses to Stravinsky's *Symphonies of Wind Instruments*: Perception of Internal Repetition and Musical Interest

Olivia Xin Wen & Carol Lynne Krumhansl
Cornell University

This experiment was designed to address factors that make repetition of musical themes within a piece recognizable, and to explore the relationship between internal repetition and musical interest. Thirty-seven participants of varied levels of music training listened to Stravinsky's *Symphonies of Wind Instruments* twice and responded to the music in real time. During the first listening, they continuously rated their level of interest and at the same time mentally identified the major themes. During the second listening, they indicated when they heard the major themes repeating. One theme was especially well recognized when repeated. It was relatively short, slow, began and ended with a predictable pattern, occurred relatively early in the piece, and was interspersed with other themes. Another theme stood out in the interest ratings, which was relatively long, fast, sometimes repeated immediately with a build-up of instrumentation and dynamics, and occurred later in the piece. In general, themes judged interesting were not those that were easily identified when repeated, suggesting these are independent aspects of this composition. No effect of music training was found. Extensive analyses of Stravinsky's *Symphonies* consider how the themes are repeated and interwoven. The experimental results confirmed the musical attributes considered in these analyses.

Received: August 1, 2015, accepted February 7, 2016.

Key words: internal repetition, musical interest, repetition structure, musical features, real-time data

A fundamental question about music is its relationship to language. Recent research is increasingly pointing to shared or similar processing mechanisms in the two domains. However, Margulis (2013a) pointed out that emphasizing the parallels between music and language sometimes overshadows insight into music's more unique qualities. One striking difference between music and language is the degree to which material is repeated. Whereas music in most styles frequently repeats melodic themes and lyrics, neither spoken language nor text typically contains frequent repetitions, especially verbatim repetitions. When verbatim repetition occurs in language it usually is for special effect, such as in poetic refrains and oratory. In addition, Margulis (2014) has suggested that surface detail is an important feature of music in contrast to language. When recalling a passage of text, gist is usually used to recap the linguistic meanings. However, because music has no gist, verbatim repetition is needed to accurately recall an earlier passage enabling listeners to re-experience the music. Thus, the importance of surface detail in music gives rise to verbatim repetition and sets music apart from language.

A number of studies have demonstrated the nature of verbatim memory for music. Both adults and children are better at recalling text when the text is embedded in music that repeats than when the text is presented as speech (Calvert, 2001; Wallace, 1994). Verbatim music repetition improved text recall in both short- and long-term memory in young adults (Calvert & Tart, 1993). Another line of evidence shows that listeners have extremely detailed memory for recorded music. For example, Krumhansl (2010) found that people could accurately identify clips of popular songs as short as 400 ms demonstrating the precise verbatim encoding of music likely resulting from repeated exposures. Commenting on the verbatim nature of music repetition, Temperley (2014) argued that every time a verbatim internal repetition recurs, the context is different. This variation in the context of the exact repetition has a positive effect on listeners' music perception because it facilitates their structural grasp of the piece and enhances their processing fluency. Temperley's point suggests that the verbatim nature of repetition both provides a reference point throughout a piece of music and serves as an integral part of the flow of music perception.

In the psychological literature, musical repetition has been touched on in a number of ways. An important

Music Perception, volume 35, issue 1, pp. 60–76, issn 0730-7829, electronic issn 1533-8312. DOI: https://doi.org/10.1525/mp.2017.35.1.60

distinction is between "external repetition," which is when an entire piece is repeated on successive occasions, and "internal repetition," which is when musical material is repeated within a single piece. We first review the literature on external repetition and then review the more recent literature on internal repetition, which is the main focus of the current study.

External Repetition

Interest in external repetition was stimulated by the mere exposure effect, which refers to the finding that increased exposure to a stimulus enhances liking (Zajonc, 1968). In support of the theory, Zajonc cites a number of earlier studies finding the effect for repeated musical pieces. Familiarity has been shown to affect musical interest for both children and adults. Bradley (1971) found that 7th graders developed strong preferences for specific pieces through repetitive listening. People also report familiarity through repetition as the most frequently given reason for liking a piece of music (Getz, 1966). Because familiarity has been tied to both external repetition and affect, it might serve as a link between the two. However, familiarity may have different effects on memorability and liking. Peretz, Gaudreau, and Bonnel (1998) first exposed listeners to a set of familiar and unfamiliar melodies in a study phase. Five minutes later, they played a larger set of melodies including the ones in the study phase. Half of the participants were asked to rate their liking of each melody, and the other half were asked to identify the melodies that they had heard earlier. They found that external repetition of familiar melodies helps recognition, whereas external repetition of unfamiliar melodies increases liking. Similarly, Russell (1987) found that external repetition of popular music has little effect on likeability even when it increases the familiarity of the songs. Tan, Spackman, and Peaslee (2006) further looked into exposure and liking, and found that repeated exposures decreased listeners' ratings of unity and liking for intact compositions, but increased those for patchwork compositions composed of sections of different pieces.

Another theory that has been considered in connection with how familiarity relates to liking is the inverted-U model (Berlyne, 1974). It predicts that as people become more familiar with a piece of music through repeated exposures, they also like the music more, up to a point where the liking reaches its maximum and then starts to decrease as it becomes too familiar. Hargreaves (1984) found, however, that the inverted-U theory seems to operate only for musical styles that listeners prefer. He also proposed the optimal complexity level depends on the relationship between objective and subjective complexity. If the objective complexity of a piece of music, measured for example by Simonton's (1980) computer-based technique, is lower than the subjective complexity judged by the listener, then liking will increase as familiarity increases. In contrast, if the objective complexity of a piece of music is higher than the subjective complexity, liking will decrease as familiarity increases. Drawing on Davies (1978) and Heyduk (1975), he suggests that subjective complexity is a function, not only of objective characteristics of the piece, but also the musical experience and sophistication of the listener. Moreover, Washburn, Child, and Abel (1927) found that in an experiment where a piece is repeated five times in succession, the point where liking is maximal depends on the genre of the music; the maximum is later for classical compositions than popular compositions.

In the context of both the mere exposure effect and the inverted-U theory, the placement of external repetitions (repeat immediately or not) seems to play a role in judgments of affect. In Verveer, Barry, and Bousfield's (1933) study, one piece of music was repeated a number of times in succession before a control piece was introduced; the control was played once before returning to the first piece. This cycle was repeated a number of times, and the whole experiment was run again a week later. In the first session, listeners' ratings of how much they liked the first piece quickly reached a maximum and then fell within the session, fitting with the inverted-U theory. However, the liking ratings for the piece started out higher at the beginning of the second session than at the beginning of the first session, which is consistent with the mere exposure effect. Also consistent with it was the finding that the liking ratings of the control piece, which was never repeated immediately, continued to increase with more repetitions. Distinguishing between successive repetition and randomly ordered repetition, Stevens and Latimer (1991) found that successive repetition increased judged pleasingness when the complexity of the composition was higher than the optimal complexity described by Hargreaves (1984), and successive repetition decreased judged pleasingness when the complexity was lower than the optimal complexity. Confirming Hargreaves's proposal of optimal complexity through successive repetition, Stevens and Latimer (1991) also found that randomly ordered repetition does not affect pleasingness.

In sum, the psychological literature on external repetition, while fairly extensive, contains some contradictory findings. At least two theories, the mere exposure

effect and the inverted U-shaped preference curve, have been influential, but sometimes make inconsistent predictions.

Internal Repetition

In contrast, the psychological literature on internal repetitions is relatively scant and recent. It does, however, point to various musical features that might be relevant. Huron (2013) proposed a psychological account of internal repetition in music based on two principles. The first is habituation, a decrease in the level of a behavioral response when a stimulus is presented repeatedly. The second is processing fluency, whereby a stimulus becomes easier to process, perceptually and/or cognitively, when it is repeated. This greater fluency leads to a positive emotional response, which is then attributed to the stimulus itself (Bornstein & D'Agostino, 1994). Through analyzing the details of these psychological principles—habituation and processing fluency—Huron developed an account to explain patterns of repetition found in music, notably the rondo and variation forms common in Western music. According to him, themes using the "rondo strategy" are repeated in their original forms, making them easy to remember; themes using the "variation strategy" are repeated with persistent slight modifications, evoking high pleasure in listeners. In addition, his account predicts that more repetition would tend to occur earlier in a piece (i.e., "rondo strategy") and more novel elements would be introduced later (i.e., "variation strategy"); this was confirmed in a cross-cultural sampling of recorded musical pieces. Despite the different approaches, Huron noted that both strategies ensure habituation and processing fluency, and can be mixed together in musical composition.

An early empirical study on internal repetitions by Pollard-Gott (1983) traced listeners' appreciation of themes in an extended composition, Liszt's *Sonata in B minor*, that was played in its entirety three times. It contains two principal themes, A and B, which are presented with variations later in the piece. After each presentation, four test excerpts representing each of the two themes were judged for similarity: A and three variations of A, and B and three variations of B. Initially, both musicians and nonmusicians grouped the excerpts on such superficial characteristics as dynamics (loud or soft), rhythm (flowing or not), and melody (jumpy or not). After repeated hearings, only the musicians started to group the test excerpts according to whether they were variations of one or the other theme. This finding suggests that the ability to recognize repeated musical themes differs between musically trained and untrained listeners only after repeated exposures. The task might have been made difficult by using variations rather than exact repetitions, which raises the question as to the degree to which listeners are sensitive to inexact repetitions as opposed to exact repetitions.

An interesting study by McAdams, Vines, Vieillard, Smith, and Reynolds (2004) asked professional musicians to play Reynolds's *The Angel of Death* in two live concerts in France and in the United States. The piece was played twice in each concert, once with the original order of two parts from the piece and the other time with the reversed order. One concert played the original order first followed by the reversed order, and the other concert did the opposite. While listening, the audience rated in real time the familiarity, or the resemblance, of musical material sounded earlier in the piece. Across the two versions and the two concerts, increasing ratings often occurred at section boundaries in the second part of the piece and the second version heard. Although not systematic for all themes, this finding indicated recognition of returning materials. Specifically, the part that had clear section boundaries between themes and other types of regions consistently received higher mean ratings in the version heard second than the one heard first, and the part where materials were interpenetrating, overlapping, and diffusing consistently received higher mean ratings when it occurred in the second half of the piece. The researchers suggested that the former was more affected by longer-term factors that persisted through pieces whereas the latter was more affected by shorter-term contextual factors.

Another study used short excerpts from four short musical excerpts by Rameau, Haydn, Schumann, and Strauss, each played four times (Margulis, 2012). Participants were asked to check a box on a computer terminal as soon as they heard some musical material repeated, which varied from a two-note gesture to an entire section, repeated immediately or later in the excerpts. Only exact repetitions were considered. A response was scored as correct if it occurred between 500 and 2000 ms of the onset of the repetition. On the first hearing, shorter repeated segments were identified more accurately than longer repeated segments. However, over the course of the four hearings, the pattern reversed such that the longer repeated segments were identified more than the shorter repeated segments. Further analyses showed that across all four hearings, repetition detection was the best when the segment was approximately six seconds in duration. Further consideration of the particular excerpts suggested other factors influencing repetition detection. Immediate repetitions were more noticeable than delayed

repetitions, especially when it occurred within the same phrase. However, another case pointed to the importance of a repeated segment ending on a point of closure. Salient opening gestures also contributed to repetition detection.

Two studies (Margulis, 2013b; Margulis & Simchy-Gross, 2016) have looked at how repetition affects evaluative judgments. The first of these used excerpts of music by modernist composers, Berio and Carter, that in the original did not contain exact repetitions. These were modified to include repetitions, which were either immediate or delayed. Participants rated all three kinds of sequences on three scales: enjoyment, interest, and artistry ("whether the music was crafted by an artist or randomly generated"). This study found that the sequences with repetitions were rated higher on all three scales, but no differences were found between immediate and delayed repetitions.

The second study (Margulis & Simchy-Gross, 2016) used randomly generated sequences of tones that were first rated for musicality. Rated at either extreme, these sequences were then played to different participants in a familiarization phase. Half of the melodies were played in the original form, while the other half were played six times in a row (looped). Finally, participants rated the sequences on musicality. The sequences that had been heard in the looped form were rated higher than those that had been played in the original form in the familiarization phase. Thus, the looped version seemed to promote its musicality, similar to the effect found when speech is looped and begins to sound musical (the speech-to-song illusion, Deutsch, Henthorn, & Lapidis, 2011).

Although the literature on internal repetition is not as extensive as for external repetition, the results point to some musical factors that may contribute to the ability to recognize repetitions. These include the placement of repetitions in a piece of music, exactness, the duration of the repeated segments, whether the repetition is immediate or delayed, whether the repeated segment begins with a distinctive opening, and whether it ends with a strong closing gesture. The literature also raises the question of what the relationship is between repetition and evaluative judgments and, if they are linked, through what psychological mechanisms.

Current Study

The music used in the experiment was Igor R. Stravinsky's *Symphonies of Wind Instruments*, which is a striking example of a composition organized around a number of themes that are repeated. For this reason, it has been the subject of extensive music theoretical analysis (Hasty, 1986; Horlacher, 2011; Kramer, 1988; van den Toorn, 1983; van den Toorn & McGinness, 2012). Stravinsky's unique style of repetition is characterized by the juxtaposition of fragmented musical themes (Horlacher, 2011). Associated and influenced by Cubist artists, notably Picasso, Stravinsky's music embodies Cubist features through copy-pasting reoccurring chunks together into one piece (Cross, 1998). In *Symphonies*, individual musical themes are often interrupted by other themes and then continue again at a later point. The discontinuity makes the themes fragmentary and unpredictable, leaving an impression of arbitrariness on the surface. Stravinsky's fragmented style makes *Symphonies* a suitable piece for the current study because of the intrinsic and subtle aspects of perception that this composition could potentially elicit.

According to Horlacher (2011), "fragments," the fragmented musical themes, can be viewed as short segments with distinctive characteristics. For simplicity, we will use the more common word "themes" for what Horlacher calls fragments. Themes in this piece are characterized by identifiable intervallic shapes (especially stepwise motion), pitches that serve as starting and ending pitches, cadential patterns (such as descending thirds), and distinctive durational patterns and rhythms. Themes are distinguished also in terms of the implicative strength, instrumentation, tempo, and duration. She develops a formalized theory called "ordered succession" that describes the complex repetition structure underlying the unpredictability of the surface details. The theory considers how often a theme is repeated, the order in which it appears, how it alternates with other themes, how varied are its repetitions, and whether it repeats immediately or at a delay.

Symphonies can be exhaustively decomposed into repetitions of eleven themes (T1–T11). Figure 1 is a theme map that displays the order of themes, their relative durations, and spacing between internal repetitions on a proportional scale of time. Table 1 summarizes some features of the themes, including some of Horlacher's (2011), and additional quantitative measures. For example, the table shows that T1, "Bell Motive," occurs seven times in total, out of which the 6 repetitions all occurred in exact forms that resemble the first occurrence. It also illustrates that except for one instance where a repetition of T1 occurs immediately after the same theme, the rest of the repetitions recur after a delay. In addition, T1 has one of the shortest average durations and has the slowest tempo as marked in the score. In contrast, T11, "Wild Dance," has no exact repetitions, it is repeated three times in succession

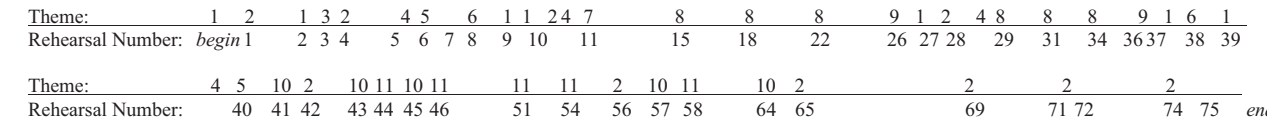

FIGURE 1. A theme map, displaying the order of themes, theme lengths, and spacing between internal repetitions of themes in *Symphonies* (Horlacher, 2011, with modifications). Themes are listed above the solid line, from left to right, starting from the top row and continuing on the bottom row. Spaces between themes are proportional to time. On the same scale of time, a selection of rehearsal numbers is listed below the solid line, locating the entrances of Themes in relation to the nearby rehearsal numbers (Kramer, 1988, with modifications). The rehearsal numbers are based on the 1947 revised version of the musical score because it is more fine-grained than the rehearsal numbers for the 1920 score (Stravinsky, 1920/1948).

TABLE 1. *Repetition Pattern of Symphonies*

		No. of Repetitions			Duration (s)		Tempo (quarter notes/minute)
Theme	Name	Total	Exact	Immediate	Total	*M* (*SD*)	
T1	Bell Motive	7	6	1	40.8	5.8 (1.7)	72
T2	Chorale	10	6	3	196.0	19.6 (13.6)	72
T3	—	1	0	0	4.0	4.0 (—)	72
T4	Russian Popular Melody 1	4	2	0	18.2	4.6 (0.2)	72
T5	Russian Popular Melody 2	2	1	0	22.4	11.2 (2.0)	108
T6	—	2	1	0	17.4	8.7 (0.1)	108
T7	—	1	0	0	27.2	27.2 (—)	108
T8	Pastorale	6	3	4	102.2	17.0 (4.1)	108
T9	—	2	1	0	12.0	6.0 (0.0)	108
T10	—	5	3	0	31.8	6.4 (2.2)	108
T11	Wild Dance	5	0	2	73.0	14.6 (7.7)	144

Note. Theme names are based on Horlacher (2011, with modifications); names for T3, T6, T7, T9, & T10 are not provided. Summary of total number of repetitions, number of exact repetitions, immediate repetitions, total duration, average duration and standard deviation, and tempo in the score for each theme (Cone, 1972; Horlacher, 2011, with modification; Kramer, 1988, with modification).

(with 2 immediate repetitions), has a relatively long duration, and is played at the fastest tempo. To anticipate the results of the present experiment, T1 was by far the easiest to recognize when it was repeated, and T11 was judged to be the most interesting. It is noteworthy that Horlacher's analysis of *Symphonies* details the contrasting characteristics of these themes and emphasizes the important roles they play in the composition.

In this experiment, we used real-time data collection, in which participants moved a slider displayed on a computer screen while they listened to the music, for a number of reasons. It has been used to reliably track responses in many tasks, such as a) segmentation, tension, musical ideas (Farbood, 2012; Krumhansl, 1996), b) memorability, openness, amount of emotion (Krumhansl, 1998), c) loudness, tempo, melodic contour, texture, timbral sharpness, emotional arousal, emotional valence (Schubert, 2004), d) familiarity/resemblance, emotional force (McAdams, et al., 2004), and e) predictability of melodies (Toiviainen & Krumhansl, 2003). In addition, it has been shown to produce inter-participant consistency across listeners with various music training backgrounds (Krumhansl, 1996). In the present study, we used the real-time response because we were interested in the details of the time course over which listeners recognized that musical material is being repeated, and we were interested in pinpointing sections of the music that were heard as most interesting.

Participants were first familiarized with the piece by hearing it one time through. They were asked to move the slider to indicate the degree to which they thought the music was interesting at each point in time, and at the same time to try to mentally identify the major themes to give them a basis for their second task: identifying repeated themes. An additional motivation for the interest rating task was Margulis's (2013b) finding that inserting repetitions into music in unfamiliar styles enhanced evaluative judgments; judgments of enjoyment, interest, and artistry showed similar effects. From these scales, we chose the interest rating as seeming most suitable to listeners with all levels of music training; judgments of enjoyment and artistry might depend on prior exposure to, and appreciation of, Stravinsky's style. Participants then performed the task of moving

the slider to indicate when they detected that a theme was repeated. They did not know they would perform this task until after making the interest judgments. The recognition of repetition responses and interest judgments will be analyzed with respect to the theoretical observations about the musical material cited above (see Table 1) and presented in detail in the Musical Analyses section.

Method

SUBJECTS

Forty-five students (age 18-25) at Cornell University participated individually for course credit or a $5 cash reward. Eight participants were excluded due to missing data because of computer error. The final analysis used data from thirty-seven participants (12 males and 25 females). On average, they had played music for 9.63 years (including music lessons; summed over all instruments and voice; range, 0–42). Thirteen participants reported that they listen to classical music. One participant reported to have listened to the piece before, and one had played many Stravinsky pieces. The study was approved by Cornell University's Institutional Review Board.

APPARATUS AND STIMULUS MATERIALS

The music was played under the control of a Power Macintosh G4 computer with the Pd-extended software of Pure Data, which was also used to collect data. The computer monitor displayed a slider, the position of which was controlled by the computer mouse and was recorded every 200 ms (see Krumhansl, 1996, 1998, for a similar interface using MAX). Participants listened to the music over AKG headphones at a comfortable loudness level. The recording was Igor R. Stravinsky's original 1920 version of *Symphonies of Wind Instruments* (9 min 16 s) played by the Berlin Philharmonic Orchestra and conducted by Pierre Boulez (Stravinsky, 1920/1999, track 1, Deutsche Grammophon 457616-2 DDD 52:04).

PROCEDURE

In the first of two tasks, participants received the following written instruction: "Listen to the music and indicate how interesting the music is at each point in time by adjusting the slider bar continuously during your listening. At the same time, try to identify mentally the major themes." This was done in order to familiarize the listener with the music. Next, a one-min practice excerpt from a 6-min long piece, Stravinsky's *Symphonies de Psaumes - 2. Expectans Expectavi Dominum,* was given to participants to familiarize them with the computer interface. They then listened to *Symphonies of Wind Instruments* and rated the level of interest by moving a slider on a continuous scale, with the right end labeled Maximal Interest and the left end Minimal Interest.

In the second task, participants received the following written instruction: "Listen to the music again and indicate when you hear the major themes repeating by adjusting the slider bar continuously." They did not know they would do this task while they were making the previous interest ratings. They then completed a practice trial with the same piece of music used in the earlier practice trial. Next, participants listened to *Symphonies of Wind Instruments* again and indicated when they heard a theme repeating by moving a slider, with the right end of the scale labeled Maximal Repetition and the left end Minimal Repetition. The scale was designed to measure their judgment on the degree to which a theme was repeated. At the end of the experiment, participants filled out a questionnaire about their demographics and music backgrounds. The experiment took approximately 30 min.

Results

REPETITION

Repetition ratings were processed in the following way. Data for all 45 segments shown in Figure 1 were analyzed for each participant. Their ratings on the continuous slider were scaled from 0 to 400, where minimal repetition was coded as 0 and maximal repetition was coded as 400. Rather than using the raw time-series data, we used the rate of change in the repetition ratings between the onset of the theme and the point at which the repetition rating reached a maximum during the theme's duration. Schubert (2002) suggested a similar differencing method as an approach to correct for effects of serial correlation in time-series data, and McAdams et al. (2004) used the first derivative of their continuous ratings to examine changes in the degree to which the musical material sounded familiar. However, instead of treating the entire time series in this way, the analyses here used one number for each of the 45 segments for each participant, indicating their rate of increase in the repetition rating during that segment's duration. Specifically, we calculated: *Rate of Increase = (Maximum Rating – Baseline Rating) / Duration between Theme Onset and Maximum Rating.* In this measure, *Maximum Rating* is the highest rating throughout the duration of a particular theme. To get a fairly stable estimate of *Baseline Rating*, which is the rating before the onset of the theme, we used the average

rating of the previous two seconds which included 10 data points. And *Duration between Theme Onset and Maximum Rating* is the time difference between the onset of a particular theme and when the rating reaches maximum for that theme. In situations where the baseline rating was larger or equal to the maximum rating, we coded the rate of increase as zero.

The mixed model analysis consisted of two random effects: Participant ID (coded as 1-37) and Theme ID (coded as 1-11). The fixed effect for Participant ID was music training based on years (0-5, 6-10, or 10+). Fixed effects for Theme ID were exact repetition (yes or no), immediate repetition (yes or no), total number of repetitions (1-10), serial order of segment (1-45), tempo (quarter note = 72, 108, or 144), segment duration (in seconds) and theme total duration (in seconds). The analyses were conducted on each fixed effect individually. It is important to note that exact repetition and immediate repetition were coded in a fashion that closely reflects available musical analyses, especially that of Kramer (1988)[1], which are described in more detail later. Other musical characteristics were based on Horlacher's (2011) musical analysis. Exact repetition was coded as yes if a particular segment is structurally similar to the first segment of the same theme according to Kramer's cell structure analysis. Immediate repetition for a particular segment was coded as yes if the segment follows another segment of the same theme without another theme in between.

Figure 2 shows the rate of increase in repetition ratings for each musical theme. Statistically, Theme 1, the "Bell Motive," distinguished itself from the rest of the themes by a Tukey HSD test; the contrast comparing Theme 1 with the other themes was highly significant, $F(1,1618) = 133.84$, $p < .0001$. Figure 3 shows the real-time repetition ratings averaged across participants. Also marked by the vertical lines are the beginning and end of all seven occurrences of Theme 1; it can be seen that the sharpest increases in the repetition ratings took place soon after it began.

The analysis found no effect of the level of music training. Results from the mixed model analysis showed that listeners of different music training backgrounds did not differ in their identification of recurring musical themes, $F(2, 34) = 0.94$, $p = .40$. The least squared mean for the less trained group (0-5 years) was 18.93, CI [12.69, 25.16], the least squared mean for the moderately trained group (6-10 years) was 15.38, CI [7.89, 22.88], and the least squared mean for the extensively trained group (10+ years) was 21.78 CI [15.97, 27.58]; all confidence intervals reported are 95%. The agreement across groups is evident in Figure 4, which shows the repetition ratings across three levels of music expertise: 0-5 years (13 listeners), 6-10 years (11 listeners), and more than 10 years (14 listeners). Thus, the less trained listeners reacted to the reoccurrence of Theme 1 as much as did moderately trained and extensively trained listeners.

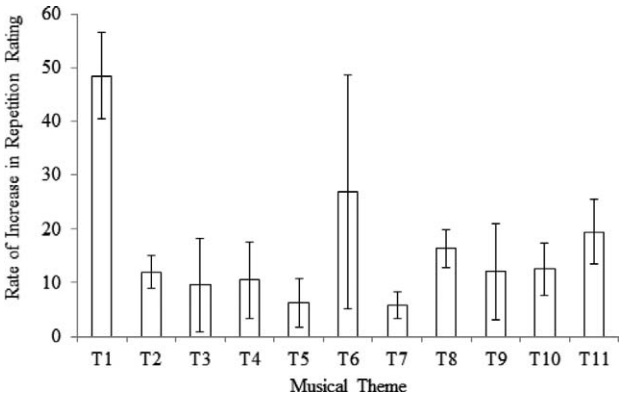

FIGURE 2. Rate of increase in repetition ratings for each musical theme averaged across participants. *Rate of Increase = (Maximum Rating − Baseline Rating) / Duration between Theme Onset and Maximum Rating.* Repetition ratings are scaled from 0–400. Error bars represent 95% confidence intervals.

The statistical analysis showed that many of the musical characteristics contributed to the recognition of themes in *Symphonies*. The rate of increase in repetition ratings was significantly and positively related to exact repetition, $F(1, 1627) = 44.32$, $p < .0001$ and marginally and positively related to total number of repetitions, $F(1, 1627) = 2.96$, $p = .09$, and negatively related to immediate repetition, $F(1, 1627) = 4.05$, $p < .05$, serial order of segment, $F(1, 1627) = 7.88$, $p < .01$, segment duration, $F(1, 1627) = 15.73$, $p < .0001$, and theme total duration, $F(1, 1627) = 9.02$, $p < .01$; themes with the moderate tempo were least recognized, $F(2, 1626) = 9.78$, $p < .0001$. To summarize, a musical theme was the most recognizable when: 1) the repetitions are exact but not immediate, 2) the theme has many repetitions, especially when they occur early in the piece, and 3) both the individual occurrences and the overall theme are relatively short in duration. This gives us a general picture of how different musical characteristics are related to the recognition of themes in this piece. In order to examine this more closely, we will consider individual themes in more detail later.

[1] Kramer's analysis is based on the 1947 version (Stravinsky, 1948), which differs only in a few details (occasional change in barring, instrumentation, or insertion of an extra measure) from the 1920 version that Horlacher (2011) used; these differences do not affect the coding of the musical characteristics considered in the statistical analysis.

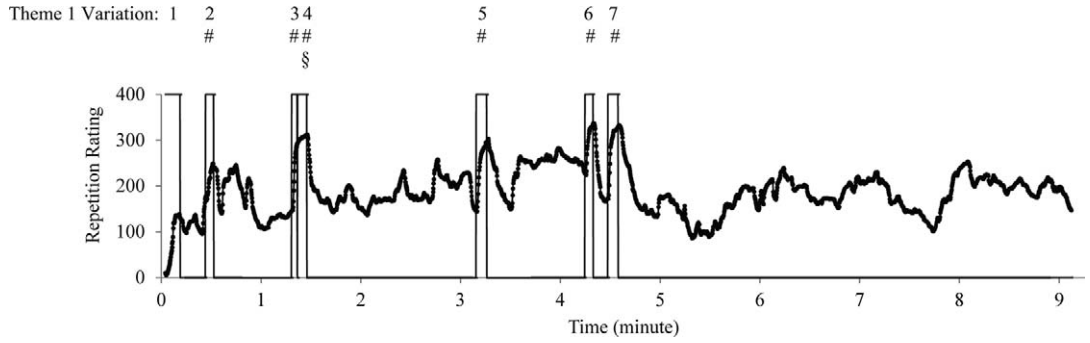

FIGURE 3. Repetition ratings averaged across participants with the beginning and end of each occurrence of the "Bell Motive" (T1) labeled by the vertical lines. # = exact repetition; § = immediate repetition.

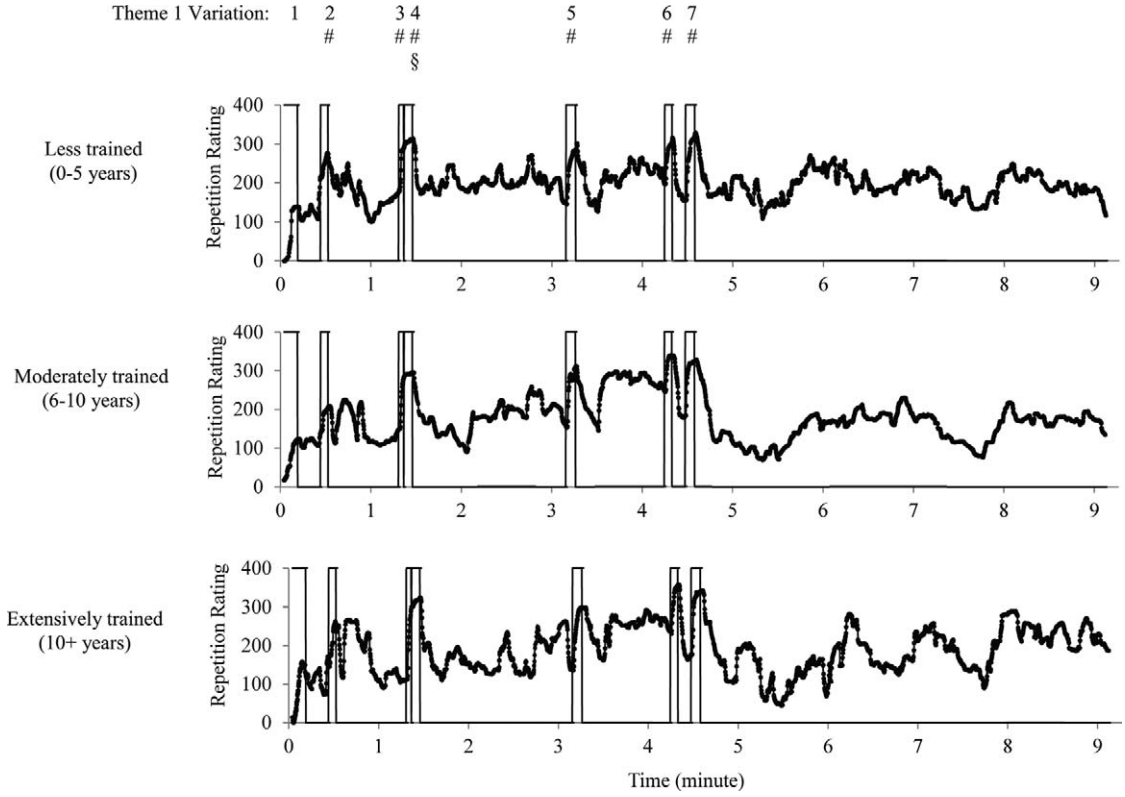

FIGURE 4. Repetition ratings with the "Bell Motive" (T1) labeled for three different levels of participant expertise based on the number of years of music training that participants have received (top: 0-5 years; middle: 6-10 years; bottom: more than 10 years). # = exact repetition; § = immediate repetition.

INTEREST

To analyze the interest ratings, we took the maximal rating given to each of the 45 segments during its entire duration because interest may peak anywhere within a segment. This was done for each participant individually. Figure 5 shows the average maximum interest ratings for each musical theme. Statistically, Theme 11, the "Wild Dance," distinguished itself from the rest of the themes by a Tukey HSD test, with the exception of Theme 7. It only occurred once and thus might have appeared novel and interesting; T7 will not be discussed further. A contrast comparing Theme 11 with the other themes was highly significant, $F(1, 1618) = 125.94$, $p < .0001$. Figure 6 shows the real-time interest ratings

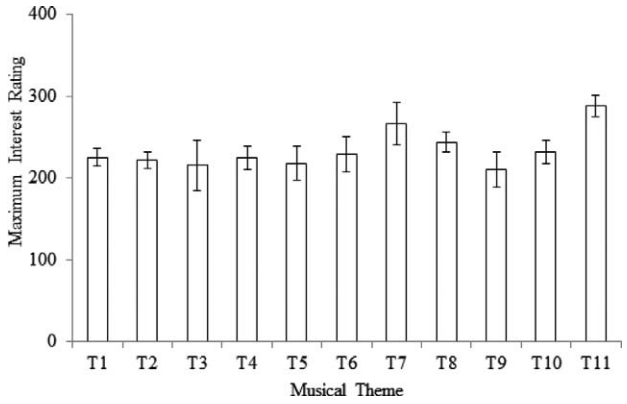

FIGURE 5. Maximum interest ratings for each musical theme averaged across participants. 0 corresponds to minimal interest and 400 corresponds to maximal interest. Error bars represent 95% confidence intervals.

averaged across participants. Also marked are the whole durations of all five occurrences of Theme 11, where the highest maximum interest ratings took place.

These interest results held true across different levels of music training. Results from the mixed model analysis showed that listeners of different music training backgrounds did not differ in their interest judgments of musical themes, $F(2, 34) = 2.33$, $p = .11$. The least squared mean for the less trained group (0-5 years) was 207.89, CI [170.24, 245.54], the least squared mean for the moderately trained group (6-10 years) was 226.88, CI [181.63, 272.13], and the least squared mean for the extensively trained group (10+ years) was 261.69, CI [226.64, 296.74]. Figure 7 illustrates interest ratings across three levels of music expertise: 0-5 years (13 listeners), 6-10 years (11 listeners), and more than 10 years (14 listeners). Listeners across the board judged that *Symphonies* reached its most interesting moment during Theme 11.

The same kind of mixed model analysis of the musical characteristics was used as with the repetition ratings. Interest was significantly and positively related to tempo, $F(2, 1626) = 73.05$, $p < .0001$, and significantly and negatively related to the total number of repetitions, $F(1, 1627) = 4.94$, $p < .05$. No other musical characteristics had significant effects on the ratings of interest. To summarize, the musical themes in *Symphonies* were judged most interesting when the theme was fast in tempo and had fewer repetitions. These results suggest that within the same piece, musical characteristics have different effects on how easily a theme is recognized and how interesting it is judged to be. To explore this in more detail, we looked at the themes that stood out most in the repetition and interest ratings, Theme 1 (the "Bell Motive") and Theme 11 (the "Wild Dance") respectively. Note that all results are specific to the case study of *Symphonies* and cannot generalize to other pieces.

COMPARING REPETITION AND INTEREST WITH THEMES 1 AND 11

Comparing Figures 2 and 5, it is clear that themes that were identified when repeated were different from those that were rated highly for interest. Table 2 lists the two sets of means from these figures. The Pearson product moment correlation between the two sets of means was $r(9) = .0002$, $p = .9996$. That repetition and interest ratings were largely independent of each other is also evident by comparing Figures 3 and 6. Thus, listeners did not find the more recognizable musical themes in this piece to be more interesting.

We conducted the same mixed model analyses with the coded musical characteristics on both repetition and interest ratings using T1 and T11 only. As Table 3 shows, all musical characteristics contributed to both ratings, however, with exactly opposite effects. In *Symphonies,* a musical theme is the most recognizable when

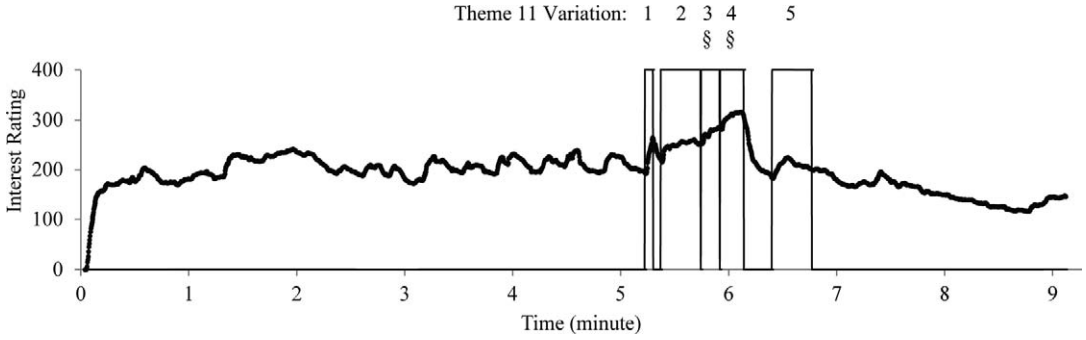

FIGURE 6. Interest ratings averaged across participants with the beginning and end of each occurrence of the "Wild Dance" (T11) labeled by the vertical lines. § = immediate repetition.

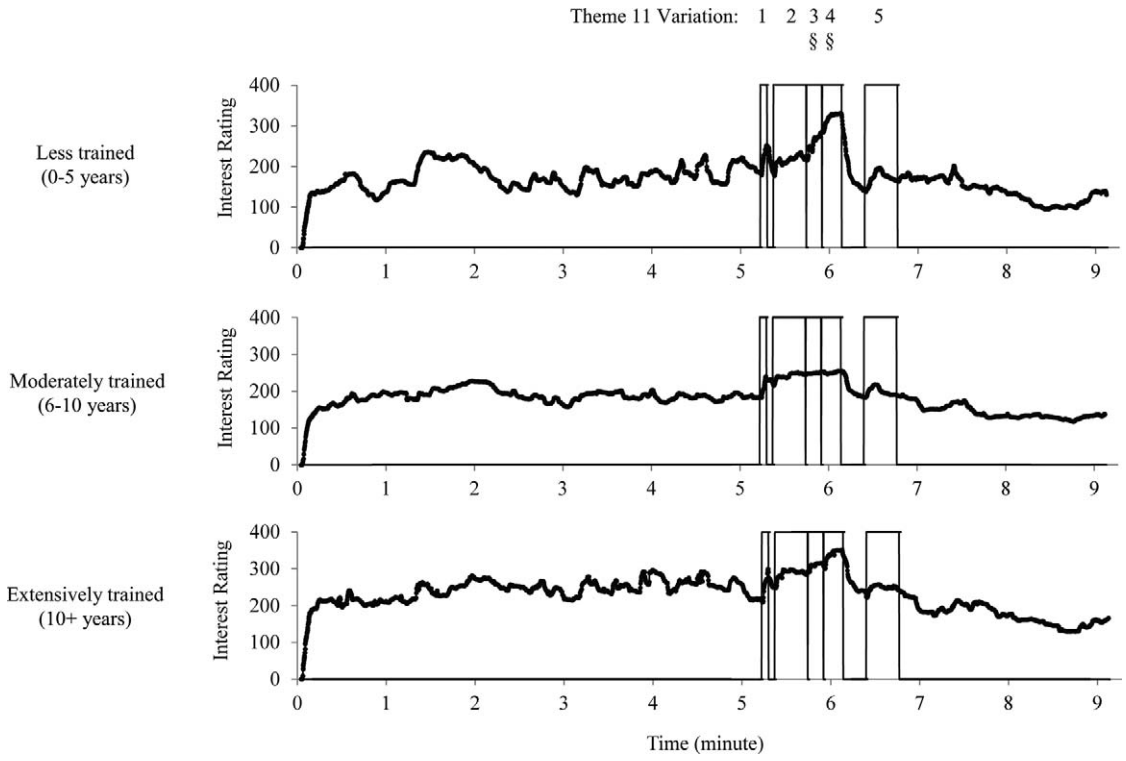

FIGURE 7. Interest ratings with the "Wild Dance" (T11) labeled for three different levels of participant expertise based on the number of years of music training that participants have received (top: 0-5 years; middle: 6-10 years; bottom: more than 10 years). § = immediate repetition.

TABLE 2. *Average Theme Ratings*

Theme	Rate of Increase in Repetition	Maximal Interest
T1	48.42	225.19
T2	12.00	221.32
T3	9.56	215.46
T4	10.46	225.07
T5	6.29	217.65
T6	26.86	228.98
T7	5.75	266.15
T8	16.35	243.51
T9	12.06	210.00
T10	12.56	231.92
T11	19.47	287.84

the repetitions are *exact* but *not immediate*, the theme has *many* repetitions, especially when they occur *early* in the piece, the theme is relatively *slow* in tempo, and both individual occurrences and the overall theme are relatively *short* in duration. In contrast, a musical theme is the most interesting in this piece of music when the repetitions are *immediate* but *not exact*, the theme has *few* repetitions, especially when it occurs *late* in a piece, the theme is relatively *fast* in tempo, and both individual occurrences and the overall theme are relatively *long* in duration. Several additional musical features might potentially have contributed to the most recognizable theme and the most interesting theme, but because of

TABLE 3. *Mixed Model Analyses for Recognition of Repetition and Maximal Interest using T1 and T11*

	Rate of Increase in Repetition Rating			Maximal Interest Rating		
Musical Feature	F (1, 406)	p	*Effect direction*	F (1, 406)	p	*Effect direction*
Exact Repetition	36.96	< .0001	+	27.70	< .0001	–
Immediate Repetition	17.38	< .0001	–	56.98	< .0001	+
Total No. of Repetitions	32.64	< .0001	+	111.48	< .0001	–
Serial Order of Segment	14.11	< .001	–	138.51	< .0001	+
Tempo	32.64	< .0001	–	111.48	< .0001	+
Segment Duration	23.91	< .0001	–	18.44	< .0001	+
Theme Total Duration	32.64	< .0001	–	111.48	< .0001	+

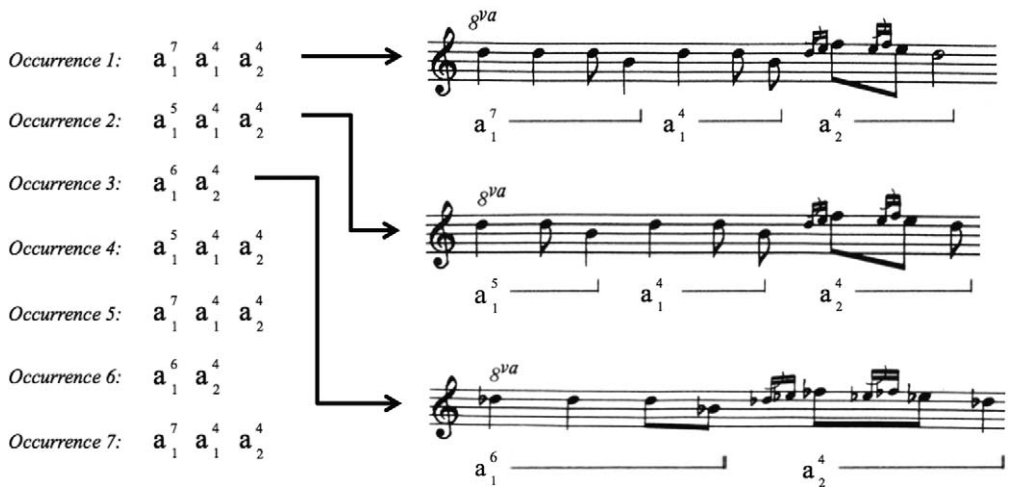

FIGURE 8. Cell structure of the "Bell Motive" in the order of its seven occurrences. Each cell is represented with the letter "a." There are two types of cells, a_1 and a_2. The subscript indicates melodic pattern and the superscript indicates duration in 8th notes. For example, in occurrence 1, a_1 occurred twice followed by one occurrence of a_2 (Kramer, 1988, with modifications).

their complex and unquantifiable nature, they were not tested statistically but will be addressed in the Musical Analyses section.

Musical Analyses

In order to gain a fuller understanding of the findings in the context of the actual music, we will discuss two examples from *Symphonies*. The first example is Theme 1, which was rated as the most recognizable musical theme when it recurred. The second example is Theme 11, which was rated as the most interesting musical theme. In this section, we will focus most attention in the analyses on these themes. Specifically, we will discuss each of the seven musical features that potentially made these two themes salient in their respective ratings. The direction of the effect will be indicated in parenthesis following each musical feature.

RECOGNITION OF REPETITIONS: THEME 1—THE "BELL MOTIVE"

Theme 1, also referred to as the "Bell Motive" by Horlacher (2011) and van den Toorn (1983), has the most recognizable repetitions (see Figure 2). One possibility is that it is the most recognizable because it is the first musical material in the piece, and thus, benefits from a primacy effect. This may well be the case, but there may be some musical reasons that it is so identifiable. To explore these, we will first explain the musical structure of the "Bell Motive." Next, we will analyze in more detail the seven musical features, namely exact repetition, lack of immediate repetition, large total number of repetitions, earlier serial order of segment, slow tempo, short segment duration, and short theme total duration, which have been shown to make repetitions of this theme easy to identify (see Table 3). Finally, we will discuss additional musical features that were not tested in the current experiment but were noted by musical theorists as a characteristic of the "Bell Motive," suggesting their likelihood of contributing to the salience of the "Bell Motive" in repetition ratings.

Cell structure. Figure 8 shows a summary of the repetition pattern of Theme 1 on the left, and on the right, the melodic notation of the first, second, and third occurrences of this theme, with their structural analysis notated below the musical score. Kramer (1988) used "cells" as the fundamental units with unique melodic patterns to organize the structure of each theme in *Symphonies*. Thus, the order in which these cells occur reflects the repetition pattern of a theme in precise detail. In the case of the "Bell Motive," each cell is represented with the letter "a," the subscript indicates the melodic pattern and the superscript indicates the duration in eighth notes. Every variation starts with one or two a_1's and ends with one a_2; a_2 always lasts for four eighth notes; when there is a second a_1, it lasts for four eighth notes while the first a_1 lasts for five or seven eighth notes; when there is only one a_1, it lasts for six eighth notes.

Exact repetition (+). These overarching or conditional rules restricted the combinations of cells to three possible options as illustrated by the musical notation. Essentially, occurrences 1, 5, and 7 share the same cell structure, occurrences 2 and 4 are identical to each other, and occurrences 3 and 6 are also exactly the same.

This limited variation of the cell structure makes the "Bell Motive" a theme that "reappears nearly intact" or with "near repeats" (Horlacher, 2011; van den Toorn, 1983). The "Bell Motive" unexceptionally starts with a_1 (Hasty, 1986). As Figure 3 shows, the rapid increase in repetition ratings following the onset of a_1 (with average duration < 2.4 s) indicates that what listeners rapidly recognized was in fact the cell a_1 in the "Bell Motive." Also, as will be discussed below, the "Bell Motive" consistently ended with the cell a_2. Thus, each repetition of the "Bell Motive" was nearly exact.

Immediate repetition (-). The placement of Theme 1 within the composition is also of interest. Figure 3 shows that, with one exception, the repetitions were not immediate, meaning that the repetitions of T1 were interspersed with other themes. The only exception was the fourth variation, an immediate repetition following the third variation. Figure 3 shows that out of all variations of the "Bell Motive," the fourth variation was the only occurrence that does not produce a rapid rate of increase in repetition ratings. Because the fourth variation shared its first note with the last note of the third variation, listeners might not have registered it as a distinct repetition. Even though the fourth variation also started with a nearly exact repetition like other variations of the same theme, the unconventional entrance may have failed to establish the independence of this variation.

Total number of repetitions (+). The exact yet non-immediate "Bell Motive" occurred for a total of seven times, making it one of the most repeated themes (see Table 1). As Figure 3 shows, the later repetitions received higher ratings. This suggests that listeners could better recognize this theme as the number of repetitions increased.

Serial order of segments (-). In addition to the placements of individual repetitions in relation to each other, another factor to consider is the placements of all occurrences of Theme 1 in relation to the entire piece of music. As the opening theme of *Symphonies*, repetitions of the "Bell Motive" tended to occur relatively early in the piece while other themes were introduced sparingly (see Figure 1 and Figure 3). According to Huron (2013), this compositional approach can be viewed as the "rondo strategy," where listeners are being habituated to repetitions of the same musical material early on, and as it dies down, they are dishabituated with novel materials. According to his theory, this strategy maximizes processing fluency by returning to the same theme, and hence making the theme easy to remember. It may also be that the theme is especially well encoded because of a primacy effect; it is the opening material of the piece.

Tempo (-). Also notice that throughout all repetitions, Theme 1 constantly maintained the slowest tempo in comparison to other themes (72 quarter notes per minute, see Table 1). This feature allows ample time for listeners to process, memorize, and encode this theme.

Segment duration (-). What resulted from the cell structure and exactness constraints on the structure of the "Bell Motive" was also that it was one of the shortest themes in the piece. All repetitions of the "Bell Motive" last for an extremely short duration, with an average of 5.8 seconds (and standard deviation of 1.7 s, see Table 1). It is interesting to note that Margulis (2012) found that the repeating musical units that were easiest to recognize were in the range of 6 s in duration; shorter or longer units were recognized less frequently.

Theme total duration (-). Despite its large number of repetitions, the total duration of this entire theme is also not long due to the short segment durations.

Syncopation (+). An additional musical feature that was not coded in the statistical analysis was syncopation because it was unclear how it might be quantified given the complex rhythms in *Symphonies*. However, the syncopation of the "Bell Motive" might have contributed to its memorability. Returning to the cell structure (see Figure 8), occurrence 1 of the "Bell Motive" starts with cell a_1, and within the duration of the first four eighth notes, the cell sets up a sense of a regular 2/4 meter. However, because the initial cell a_1 lasts for seven eighth notes in the first occurrence, the second cell a_1 appears to come in on an offbeat. In subsequent repetitions, the duration of the first cell a_1 varies between five, six, and seven eighth notes (e.g., occurrence 2: five eighth notes, occurrence 3: six eighth notes, etc.). This makes the entrance of the second cell a_1 sounds on-the-beat at times but off-the-beat at other times without disrupting the intact nature of the theme. As van den Toorn (1983) and van den Toorn and McGinness (2012) suggested, this juggling might introduce a renewed sense of rhythmic-metric identity.

Closure (+). Finally, another musical feature that was not explicitly coded in the current study was closure. Musically, the "Bell Motive" always ends with a_2 on the same note that it started with, closing with a descending third back to a relatively stable pitch (Horlacher, 2011). As Horlacher noted, unlike other themes that are stretched and subject to many degrees of variation that affect their closure, the "Bell Motive" is self-enclosed. This consistent closure marked by a_2's determinant ending allows the "Bell Motive" to mark its conclusion after every repetition.

MAXIMAL INTEREST: THEME 11—THE "WILD DANCE"

Theme 11, referred to as the "Wild Dance" by Horlacher (2011), was rated as the most interesting musical theme (see Figure 5). Specifically, Figure 6 shows that the second, the third, and the fourth occurrences form a chain of immediate repetitions that builds up the interest rating to the climax of the entire piece. To examine possible underlying reasons, we will first analyze in more detail the seven musical features, namely lack of exact repetition, immediate repetition, small total number of repetitions, later serial order of segment, fast tempo, relatively long segment duration, and relatively long theme total duration, which have been shown to promote interest ratings. Next, we will focus on the climax by discussing additional musical features that were not explicitly coded in the analyses. However, they were noted by music theorists as characteristic of the "Wild Dance," suggesting their possible contribution to the salience of the "Wild Dance" in the interest ratings.

Exact repetition (-). Similar to the "Bell Motive," the "Wild Dance" also follows a cell structure (not illustrated due to unnecessary complexity[2]). However, unlike the "Bell Motive," where cells are nearly exact across occurrences, the cells of the "Wild Dance" have a wide range of variations across occurrences, resulting in the fact that out of 20 separate versions of the cell in the "Wild Dance," no version is played more than twice (Kramer, 1988). Thus, compared to the "Bell Motive" which provided stability, the "Wild Dance" raised possibilities for variation (Horlacher, 2011). In contrast to Huron's (2013) "rondo strategy" that the "Bell Motive" employed, the compositional approach of the "Wild Dance" can be viewed as his "variation strategy," where listeners are exposed to modifications of repeated passages, reducing their likelihood of habituation to the present musical material.

Immediate repetition (+). One particularly notable feature of the "Wild Dance" is that three out of the five occurrences were played in succession (see Figure 6). Coincidentally, the build-up to the climax took place during the same occurrences, making immediate repetition an important contribution to the high interest ratings. Combined with the lack of exact repetition, people's affectivity seems to increase when non-verbatim repetitions are played immediately after one another, which is the opposite to the scenario of the "Bell Motive" where verbatim repetitions are played in a dispersed fashion.

[2] As explained in detail by Kramer (1988, pp. 266-275), the cell structure of Theme 11, the "Wild Dance," is quite complex and his analysis entails special notation, so it will not be displayed here.

Total number of repetitions (-). Despite the fact that the "Wild Dance" is not the most repeated theme, listeners found it the most interesting (see Figure 5), which suggests that listeners' interest is enhanced by the novelty of the material instead of the number of repetitions.

Serial order of repetition (+). In this 9 min, 16 s piece, the "Wild Dance" first occurred at 5 min, 13 s, making it the theme with the latest entrance. As Horlacher put it, the "Bell Motive" and the "Wild Dance" are two distinct cases of reiteration across the piece. Essentially, the former was placed as the opening theme and lasted throughout the first half of the piece whereas the latter did not appear until more than half way through the piece yet dominated the rest of it.

Tempo (+). One type of feature to consider is temporal factors, such as tempo. Theme 11 has the fastest tempo in the entire piece (144 quarter notes per minute, see Table 1).

Segment duration (+). In addition, the "Wild Dance" has a relatively long segment length (mean duration, see Table 1), especially in comparison to the "Bell Motive," the most recognizable theme.

Theme total duration (+). Due to the long segment durations, the total duration of this theme is also relatively long. This likely facilitated the development across occurrences of the already complex musical materials.

Syncopation (+). An additional temporal feature that was not explicitly coded in the analyses concerns its rhythmic complexity. Similarly to the "Bell Motive," the offbeat entrances of cells create a sense of syncopation, drawing attention from listeners. Adding to the interplay of beats and meters, Stravinsky selectively utilized the bass line to accent cells with the most striking melodic profile in the third occurrence of the "Wild Dance" (Kramer, 1988). An accent pattern like this generates high levels of unpredictability. In addition, in the fourth occurrence of the theme, a syncopated counterpoint between the upper and lower brass develops gradually from the initial rhythmic unison, adding to the existing rhythmic complexity towards the climax (Kramer, 1988).

Because syncopation contributes to both repetition and interest ratings, it is an exception compared to the rest of the musical features where the directions of effect are opposite in the two ratings. On one hand, this suggests that syncopation might be an attention-getting feature that amplifies the impact of other musical features in a theme (e.g., syncopation in a theme with exact repetition makes the theme more recognizable; syncopation in a theme with inexact repetition makes the theme more

TABLE 4 *Instrumental Features of Theme 11*

Occurrences	No. of Instrument Types	No. of Instrumental Parts	No. of Instruments
1	6	8	10
2	5	7	10
3	7	12	15
4	9	14	20
5	3	3	4

Note. Reported are the maximal numbers during each occurrence.

interesting). On the other hand, syncopation might not be a defining feature for the "Bell Motive" and the "Wild Dance" because, despite the strong emphasis that musical analyses put on these two themes, syncopation also occurred in several other themes (Kramer, 1988).

Closure (-). Another musical feature that was not explicitly coded was closure. Although the "Wild Dance" is viewed as a theme with determinant ending (Horlacher, 2011), it is only so for the first, the fourth, and the fifth occurrences. In other words, the three occurrences in the middle that build up to the climax in interest ratings only have one closure at the end of the three occurrences (see Figure 6). Rather, the lack of closure might have enhanced listeners' liking of the theme by maintaining their attention until the music is finally resolved at the end of the climax.

Instrumental features (+). One other untested feature that might contribute to the salience of the "Wild Dance" is the build-up of timbre, instrumental parts, and dynamics towards the climax. Table 4 summarizes the maximal number of these instrumental features for each of the five occurrences of Theme 11. Throughout the build-up towards the peak of interest (the second, third, and fourth occurrences), the "Wild Dance" started with 5 types of instruments and ended with 9, the instrumental parts were doubled from 7 to 14, and the actual number of instruments was also doubled from 10 to 20. These instrumental features likely contributed to the salient interest ratings during the build-up towards the climax at three different levels. First, the nearly doubled variety of timbre enriched the theme, making it sound more diverse and interesting. Second, the steep increase in instrumental parts added to the complexity of note combinations at each moment. These combinations could be interpreted as various possible chords that overlap and share notes with each other. Consequently, this expanded possibility of chords led to increasing unpredictability in vertical sonority, making the climax the most ambiguous moment and hence the most interesting moment (Straus, 1981). And third, the firm increase in the actual number of instruments boosted listeners' excitement by increasing the dynamic to the loudest point of the entire piece at the end of the fourth occurrence.

Discussion

In an effort to explore the repetitive nature of music and its relationship to evaluative judgments of music, we conducted a case study using Stravinsky's *Symphonies*. Through listeners' recognition of recurring musical themes and their interest judgments, we identified a number of musical features that may promote a theme to be recognizable or to be interesting. In order to pinpoint these features in the context of music, we analyzed the most salient theme in each of the two ratings. Overall, the current study shows that in the case of *Symphonies*, features associated with the repetitive nature of music do not overlap with those associated with musical interest. Although the finding that repetition and interest were independent in this study does not undermine the uniqueness and importance of repetition in music, the current study does suggest that repetition and interest can be independent aspects of the musical experience.

Although *Symphonies* is intrinsically repetitive because it is organized around recurring musical themes, only one theme stood out as recognizable, namely Theme 1, the "Bell Motive." Statistical analyses showed that in this piece, the longer absolute duration of a musical theme was not essential for making a theme recognizable; instead, what mattered were the exactness, the dispersed yet earlier placement in time, the large number of repetitions, the slow tempo, and the short (6 s) segment duration. Together with other untested features (i.e., syncopation and closure), they help focus listeners' attention and increase their processing fluency as proposed by Temperley (2014), which make Theme 1 highly memorable. The compositional approach of Theme 1 can be viewed as an example of Huron's (2013) "rondo strategy," which will be discussed later.

The salience of Theme 1 is consistent with Margulis's (2012) finding that 1) 6 seconds is the optimal length of repeating musical units for easiest recognition, 2) salient openings (syncopation in the case of Theme 1 in *Symphonies*) play a crucial role in theme recognition, and 3) ending a repeated segment at a point of closure facilitates recognition. However, Theme 1 also contradicts Margulis's (2012) finding that immediate repetitions are more noticeable, which might be specific to the within-phrase repetitions in her study and might not be suitable for the longer repeated units in *Symphonies*. In correspondence with McAdams et al. (2004) where the

memory of themes with clear boundaries was longer-lasting than the memory of those with interpenetrating elements, Theme 1 possesses characteristics of the former and was significantly better recognized compared to other themes that are more similar to the latter. These findings complement each other as they both highlight the benefit of having clear opening and closure on theme recognition. Regarding Pollard-Gott's (1983) finding that only after repeated listening could musically trained listeners recognize variations of corresponding themes, the salience of Theme 1 offers the explanation that the task was made challenging by using variations (i.e., inexact repetitions).

In terms of judgments of interest, Theme 1 did not stand out. Instead, Theme 11, the "Wild Dance," was rated as the most interesting theme. Interestingly, all seven features are pointing towards the opposite directions from the equivalent features associated with the memorability of Theme 1. Statistical analyses showed that in *Symphonies*, the exactness and the large number of repetitions were not essential for making a theme interesting; instead, what mattered were the concentrated (i.e., immediate) yet later placement in the piece, the fast tempo, and the relatively long segment duration and total duration of a musical theme. Combined with other untested features that are related to the climax of the piece (i.e., syncopation, closure, and instrumental features), Theme 11 excelled in complexity and unpredictability, making it sound exciting and distinguishably interesting. The compositional approach of Theme 11 can be viewed as an example of Huron's (2013) "variation strategy," which will be discussed later.

Unlike Margulis's (2013b) finding that exact repetition contributes to interest ratings of modern music pieces, Theme 11, the one with the highest interest rating, lacked exact repetition, and Theme 1, the one with the most exact repetitions, was not rated as interesting. This inconsistency with the previous finding suggests that the relation between exact repetition and interest is not absolute and that it can be better understood in the context of other musical features. In addition, the small number of repetitions in Theme 11 contradicts the mere exposure effect, which refers to the idea that in the realm of external repetition, exposure (Zajonc, 1968) and familiarity (Getz, 1966) enhance liking. This contradiction suggests that listeners' processing of internal repetition might differ from that of external repetition. Similarly, the current study shows no support for the inverted-U theory, which refers to the idea that exposure and familiarity enhance liking until a maximum point where liking starts to decline. This lack of support from the current study might be an evidence for Hargreaves's (1984) claim that the inverted-U theory only works for musical styles preferred by listeners. However, given that this theory was intended to address external repetitions, this lack of support could also suggest different processes between internal and external repetitions.

Related to compositional approaches, Stravinsky's structural organization of the musical themes can be understood based on Huron's (2013) two strategies, the "rondo strategy" and the "variation strategy." Theme 1 demonstrates the "rondo strategy" because it was introduced early in a repetitive fashion. In contrast, Theme 11 demonstrates the "variation strategy" because it was introduced late in an unpredictable fashion. Consistent with their corresponding strategies, Theme 1 was shown to be memorable whereas Theme 11 was shown to be pleasurable.

It is important to note that the results of this case study, which intensively examined a single composition, cannot generalize to other pieces. The approach has the advantage, however, that this composition has received such detailed theoretical analysis that can guide the interpretation of the perceptual results, which are tracking moment-to-moment reactions to the music in real time. Moreover, the convergence between the statistical and musical analyses generate specific findings that might contribute to more general theories of and empirical results on repetition in music.

Author Note

We are grateful for the technical assistance of Kevin Ernst and the statistical consultation of Francoise Vermeylen, and thank Julia Klein for conducting some of the experimental sessions. We would also like to thank the reviewers for their thoughtful comments and suggestions on an earlier draft of the article.

Correspondence concerning this article should be addressed to Correspondence concerning this article may be sent to Carol Lynne Krumhansl, Department of Psychology, Uris Hall, Cornell University, Ithaca, NY 14853. E-mail: clk4@cornell.edu

References

Berlyne, D. E. (1974). Novelty, complexity and interestingness. In D. E. Berlyne (Ed.), *Studies in the new experimental aesthetics* (pp. 175-181). Washington, DC: Hemisphere.

Bornstein, R. F., & D'Agostino, P. R. (1994). The attribution and discounting of perceptual fluency: Preliminary tests of a perceptual fluency/attributional model of the mere exposure effect. *Social Cognition, 12*, 103-128.

Bradley, I. L. (1971). Repetition as a factor in the development of musical preferences. *Journal of Research in Music Education, 19,* 295-298.

Calvert, S. L. (2001). Impact of televised songs on children's and young adults' memory of educational content. *Media Psychology, 3,* 325-342.

Calvert, S. L., & Tart, M. (1993). Song versus verbal forms for very-long-term, long-term, and short-term verbatim recall. *Journal of Applied Developmental Psychology, 14,* 245-260.

Cone, E. T. (1972). Stravinsky: The progress of a method. In B. Boretz & E. T. Cone (Eds.), *Perspectives on Schoenberg and Stravinsky* (pp. 155-164). New York: Norton Press.

Cross, J. (1998). *The Stravinsky legacy.* New York: Cambridge University Press.

Davies, J. B. (1978). *The psychology of music.* London, UK: Hutchinson.

Deutsch, D., Henthorn, T., & Lapidis, R. (2011). Illusory transformation from speech to song. *Journal of the Acoustical Society of America, 129*, 2245-2252.

Farbood, M. M. (2012). A parametric, temporal model of musical tension. *Music Perception, 29,* 387-428.

Getz, R. P. (1966). The effects of repetition on listening response. *Journal of Research in Music Education, 14,* 178-192.

Hargreaves, D. J. (1984). The effects of repetition on liking for music. *Journal of Research in Music Education, 32,* 35-47.

Hasty, C. F. (1986). On the problem of succession and continuity in twentieth-century music. *Music Theory Spectrum, 8,* 58-74.

Heyduk, R. G. (1975). Rated preference for musical composition as it relates to complexity and exposure frequency. *Perception and Psychophysics, 17,* 84-91.

Horlacher, G. G. (2011). *Building blocks: Repetition and continuity in the music of Stravinsky.* New York: Oxford University Press.

Huron, D. (2013). A psychological approach to musical form: The habituation-fluency theory of repetition. *Current Musicology, 96*, 7-35.

Kramer, J. D. (1988). *The time of music: New meanings, new temporalities, new listening strategies*. New York: Schirmer Books Press.

Krumhansl, C. L. (1996). A perceptual analysis of Mozart's Piano Sonata K. 282: Segmentation, tension, and musical ideas. *Music Perception, 13,* 401-432.

Krumhansl, C. L. (1998). Topic in music: An empirical study of memorability, openness, and emotion in Mozart's String Quintet in C Major and Beethoven's String Quartet in A Minor. *Music Perception, 16,* 119-134.

Krumhansl, C. L. (2010). Plink: "Thin slices" of muisc. *Music Perception, 27,* 337-354.

Margulis, E. H. (2012). Musical repetition detection across multiple exposures. *Music Perception, 29,* 377-385.

Margulis, E. H. (2013a). Repetition and emotive communication in music versus speech. *Frontiers in Psychology, 4,* 1-4.

Margulis, E. H. (2013b). Aesthetic responses to repetition in unfamiliar music. *Empirical Studies of the Arts, 31,* 45-57.

Margulis, E. H. (2014). *On repeat: How music plays the mind.* New York: Oxford University Press.

Margulis E. H., & Simchy-Gross, R. (2016). Repetition enhances the musicality of randomly generated tone sequences. *Music Perception, 33,* 509-514.

McAdams, S., Vines, B. W., Vieillard, S., Smith, B. K., & Reynolds, R. (2004). Influences of large-scale form on continuous ratings in response to a contemporary piece in a live concert setting. *Music Perception, 22*, 197-350.

Peretz, I., Gaudreau, D., & Bonnel, A. (1998). Exposure effects on music preference and recognition. *Memory and Cognition, 26*, 884-902.

Pollard-Gott, L. (1983). Emergence of thematic concepts in repeated listening to music. *Cognitive Psychology, 15,* 66-94.

Russell, P. A. (1987). Effects of repetition on the familiarity and likeability of popular music recordings. *Psychology of Music, 15,* 187-197.

Schubert, E. (2002). Correlation analysis of continuous emotional response to music: Correcting for the effects of serial correlation. *Musicae Scientiae, 32,* 561-585.

Schubert, E. (2004). Modeling perceived emotion with continuous musical features. *Music Perception, 32,* 561-585.

Simonton, D. K. (1980). Thematic fame and melodic originality in classical music: a multivariate computer-content analysis. *Journal of Personality, 48,* 206-219.

Stevens, C., & Latimer, C. (1991). Judgments of complexity and pleasingness in music: The effect of structure, repetition, and training. *Australian Journal of Psychology, 43,* 17-22.

Straus, J. N. (1981). *A theory of harmony and voice leading in the music of Igor Stravinsky.* Ann Arbor & London: University Microfilms International.

Stravinsky, I. R. (1920). Symphonies of wind instruments [Recorded by Berlin Philharmonic Orchestra, 1999]. On *Stravinsky: Symphony of psalms; Symphony in three movements; Symphonies of wind instruments* [CD]. Hamburg, Germany: Deutsche Grammophon 457616-2 DDD 52:04.

Stravinsky, I. R. (1948). *Symphonies of wind instruments* [Score and parts]. London, New York: Boosey & Hawkes. (Original work composed 1920)

Tan, S-L., Spackman, M. P., & Peaslee, C. L. (2006). The effects of repeated exposure on liking and judgments of musical unity of intact and patchwork compositions. *Music Perception, 23,* 407-421.

Temperley, D. (2014). Review of the book "On repeat: How music plays the mind" by E. H. Margulis. *Music Perception, 32,* 216–218.

Toiviainen, P., & Krumhansl, C. L. (2003). Measuring and modeling real-time response to music: The dynamics of tonality induction. *Perception, 32,* 741-766.

van den Toorn, P. C. (1983). *The music of Igor Stravinsky.* New York: Vail-Ballou Press.

van den Toorn, P. C., & McGinness, J. (2012). *Stravinsky and the Russian period: Sound and legacy of a musical idiom.* New York: Cambridge University Press.

Verveer, E. M., Barry, Jr., H., & Bousfield, W. A. (1933). Change in affectivity with repetition. *The American Journal of Psychology, 45,* 130-134.

Wallace, W. T. (1994). Memory for music: Effect of melody on recall of text. *Journal of Experimental Psychology, 20,* 1471-1485.

Washburn, M. F., Child, M. S., & Abel, T. M. (1927). The effect of immediate repetition on the pleasantness or unpleasantness of music. In M. Schoen (Ed.), *The effects of music* (pp. 199-210). New York: Harcourt, Brace.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology, 9,* 1-27.