Expectancy Effects in Memory for Melodies

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Abstract Two experiments explored the relation between melodic expectancy and melodic memory. In Experiment 1, listeners rated the degree to which different endings confirmed their expectations for a set of melodies. After providing these expectancy ratings, listeners received a recognition memory test in which they discriminated previously heard melodies from new melodies. Recognition memory in this task positively correlated with perceived expectancy, and was related to the estimated tonal coherence of these melodies. Experiment 2 extended these results, demonstrating better recognition memory for high expectancy melodies, relative to medium and low expectancy melodies. This experiment also observed asymmetrical memory confusions as a function of perceived expectancy. These findings fit with a model of musical memory in which schematically central events are better remembered than schematically peripheral events.

The generation of expectations has been recognized as a central factor in listeners' perceptions of music. Simply defined, "expectation" refers to the anticipation of upcoming information based on past and current information. The concept of expectancy has traditionally received, and continues to receive, a great deal of attention from both a music-theoretic (e.g., Meyer, 1956, 1965; Narmour, 1989, 1990, 1992) and psychological viewpoint (e.g., Bharucha, 1987, 1994; Carlsen, 1981, 1982; Carlsen, Divenyi, & Taylor, 1970; Cuddy & Lunney, 1995; Dowling, 1994; Jones, 1976, 1981, 1982, 1990; Krumhansl, 1995; Schellenberg, 1996, 1997; Schmuckler, 1989, 1990; Schmuckler & Boltz, 1994; Unyk & Carlsen, 1987).

Given this interest, it is not surprising that expectation has been found to play a critical role in many aspects of musical processing. One such area involves listeners' judgments of, and responses to, musical passages. For example, Schmuckler (1989) had listeners provide goodness-of-fit ratings for a set of continuations of melodic, harmonic, and combined melodic-harmonic passages. These studies uncovered systematic variation in listeners' judgments of these continuations, with some endings receiving high expectancy ratings, whereas other endings received relatively low expectancy ratings. Additionally, these studies demonstrated that expectancies were predictable from various music-theoretic and perceptual/cognitive principles of pattern organization. Similar results have been observed by Cuddy and Lunney (1995), Krumhansl (1995), and Schellenberg (1996), in their tests of Narmour's (1990, 1992) implication-realization model. Together, these findings suggest that judgments of a musical event vary with the perceived expectancy of that passage, with expectations quantifiable on the basis of a range of factors.

A second area in which expectancies play a role in musical perception is the processing and encoding of musical information. For example, Bharucha and colleagues (Bharucha & Stoeckig, 1986, 1987; Tekman & Bharucha, 1992) demonstrated priming effects in musical contexts, in which a target event (a musical chord) is responded to more quickly and accurately following a harmonically (i.e., semantically) related prime chord, relative to when a harmonically unrelated prime preceded the target. Similarly, Bigand and Pineau (1997) have recently demonstrated influences of global (e.g., multi-event) musical contexts on both judgments and processing speed for harmonic events. These findings are well-captured by a connectionist model of the psychological representation of tonal-harmonic information (Bharucha, 1987), with this model quantifying expectancy formation via spreading activation among musical units. In the same vein, Schmuckler and Boltz (1994), using complex, realistic passages, examined both listeners' judgments of musical events and the speed of processing of these events, and found that expectancy ratings and processing speed were influenced not only by patterns of harmonic relatedness, as expressed in Bharucha's model, but also by the rhythmic structure of the musical information; this last factor has not been explicitly represented in connectionist

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architectures of harmonic relatedness.

A third area in which expectancy plays a role is the production and performance of musical information (Carlsen, 1981; Schellenberg, 1996; Schmuckler, 1989, 1990; Thompson, Cuddy, & Plaus, 1997; Unyk & Carlsen, 1987). For example, Carlsen (1981) and Unyk and Carlsen (1987) had listeners sing continuations in response to different two-note context intervals, with the intervals between the second note of the context and the first note of the listener-produced sequence (the "response interval") analysed in terms of their frequency of occurrence as a function of the context intervals. These studies demonstrated that response intervals varied in their size, as well as their specificity, with some context intervals producing only a single response interval whereas others generated a range of responses. In a different vein, Schmuckler (1989) had pianists complete different melodic and combined harmonic-melodic contexts and found that performers' productions mirrored expectancy judgments, with tones that had received high expectancy ratings in the previous perceptual studies produced more frequently than low expectancy tones. Subsequent analyses of these performances (Schmuckler, 1990) found that both global musical factors, such as tonal (e.g., Krumhansl & Shepard, 1979; Krumhansl & Kessler, 1982) and rhythmic (e.g., Palmer & Krumhansl, 1989) hierarchies, as well as local contextual factors, such as patterns of pitch and metrical information contained in the to-be-completed contexts, were all important factors in determining the content of these productions. One aspect of this work is that the majority of these studies have focused on the anticipation of the single next event in a sequence, or what Jones (1981, 1982, 1990) calls "expectancies," without examining anticipations of more extended, multi-event completions, or "expectancy schemes" (Jones, 1981, 1982, 1990; but see Schmuckler, 1990, for an exception). Despite this limitation, however, these studies do suggest that expectations influence both perceptions, as well as productions of musical passages, with similar processes operative in both perception and performance.

One aspect that has not received much attention in expectancy research is the influence of expectations on subsequent memory for music. Some closely related work on dynamic attending by Boltz and Jones (e.g., Boltz & Jones, 1986), however, strongly suggests that expectancy formation will affect musical memory. For example, Boltz (1991, 1992a, 1992b, 1993) demonstrated that expectancy formation affords better encoding of information by guiding one's attention towards particular points in time at which structurally important information occurs. In Boltz (1991), memory for unfamiliar folk melodies was facilitated when the occurrence of tonally significant information coincided with a corresponding pattern of temporal accents. One interpretation of this result is that the regular accent structure enabled listeners to generate expectations towards specific points in time, with this guided attention causing more accurate encoding, and hence better recall, of the melodies. Similarly, Boltz (1993) found that expectancy generation, which relied upon both periodic accent structure and melodic markers of phrase boundaries, facilitated melody recognition, with the temporal dimension affecting recognition more than melodic factors.

Additionally relevant data has been provided by Boltz, Schulkind, and Kantra (1991). In this work, the placement of music during a film was manipulated such that the music either accompanied a scene's outcome, thereby accentuating its meaning, or foreshadowed the scene, thereby generating expectancies concerning the scene's outcome. Boltz et al. (1991) also manipulated the affective character of the music, making it either congruous or incongruous with the scene's outcome. Subsequent memory tests for these scenes found that these factors interacted, with mood-incongruent information producing better memory for the scene in the foreshadowing condition, whereas mood-congruent information lead to better performance in the concurrent condition. This finding suggests that expectancy generation influenced memory for events, with expectancy violations (e.g., foreshadowed mood-incongruent information) producing better recall.

Overall, Boltz's work suggests that expectancy formation will have an impact on subsequent memory for such information. It should be noted, however, that the primary goal of these studies has been to examine the impact of guided attention on processing and memory, with these studies primarily (albeit not exclusively) manipulating temporal and rhythmic factors. One consequence of this focus is that this work has not systematically explored the impact of pitch and tonal variations on expectancies and memory, nor has it provided any direct measure of expectations for this material. Thus, although expectations for upcoming information will be clearly influenced by both temporal/rhythmic and tonal/pitch information (see Jones, 1981, 1982), it is unclear how systematic variation of expectancies on the basis of tonal/pitch information, with rhythmic/temporal information held constant, will influence memory for such information; examining this question is the goal of the current study.

One reason to suspect that memory for music might be affected by differences in the expectedness of pitch information is that musical memory and musical expectancies are both influenced by a common factor – that of musical tonality. Evidence suggesting that tonality impacts on expectancy generation has been provided in numerous studies (e.g., Cuddy & Lunney, 1995; Krumhansl, 1995;

Schellenberg, 1996; Schmuckler, 1989, 1990), and demonstrates that tonally central information (e.g., diatonic tones) is more expected that tonally peripheral information. There is similarly a great deal of evidence implicating a role for tonality in musical memory. For example, Krumhansl (1979, Experiments 2 and 3) investigated memory for a standard tone when this note was followed by either a tonal or an atonal intervening sequence. When intervening sequences were tonal, memory for the standard was best if this standard was a tonally important note in the intervening sequence, relative to when this note was drawn from outside the key of the intervening sequence. For atonal contexts, non-diatonic standards were better remembered than diatonic standards. Thus, musical tonality affects memory for isolated musical information, such as single tones.

Tonality also influences memory for more extended musical passages, such as melodies. For example, research has shown that memory for tonal melodies is better than memory for atonal melodies (Cuddy, Cohen, & Mewhort, 1981; Cuddy, Cohen, & Miller, 1979; Francès, 1988). Similarly, Bartlett and Dowling (1980), again using a standard-comparison recognition memory procedure, found that it was difficult to reject (different) comparison melodies when both standard and comparison were drawn from musically related tonalities, relative to when the melodies were tonally unrelated. Other studies (Dowling & Bartlett, 1981; DeWitt & Crowder, 1986) found that the importance of tonal information in melodies increases in long-term, relative to short-term memory. Finally, Dowling, Kwak, and Andrews (1995) examined melody recognition, using melodies varying in their pitch interval information and contour. This work demonstrated that pitch interval information was more important after long delays filled with intervening stimuli, with the encoding of such melodies facilitated when they contained a coherent tonality. Together, this work provides clear evidence that tonality influences memory for musical information.

Assuming a relation between expectancy and memory, how might this relation be characterized? One candidate model is that expectancy and memory will be positively correlated, with high expectancy information better remembered than low expectancy information. This prediction grows out of the idea that, relative to low expectancy information, highly expected materials are more consistent with one's general musical schema. Thus, schematically central (i.e., high expectancy) information will be better remembered than more schematically peripheral (i.e., low expectancy) information (Bartlett, 1932).

Along with predicting that expectancy and memory will be positively related, this "schema" model also suggests that in recognizing melodies, memory confusions may be asymmetric. Because highly expected events are central to one's schema, these events will be less susceptible to memory distortions, compared to unexpected, schematically peripheral events. One potential distortion is that the irregularities of unexpected events will be remembered as more expected than they actually were. Thus, unexpected events will be often confused with expected events, whereas expected events will be rarely confused with unexpected events.

A second model of the relation between expectancy and memory is based on the well-known von Restorff effect (1933; see Wallace, 1965, for a review), in which isolating an item from its background enhances learning of the item, with subsequent memory for this item superior to memory of non-isolated elements. Along these lines, unexpected events would "stick out," or become isolated, rendering them more distinctive and memorable; hence, expectancy and memory should be negatively related. This hypothesis is, in fact, in keeping with Boltz et al.'s (1991) findings in which mood-incongruent music foreshadowing a scene led to better recall than did mood-congruent music. Presumably, foreshadowing enabled observers to generate expectations for the upcoming scene. When these expectancies were violated, as would occur with mood-incongruent music, the events became distinctive.

The experiments described in this paper explore the impact of musical expectancies on memory for melodies, examining these two theoretical characterizations of this relation. Along with assessing the relation between expectancy and memory, these studies also examine the impact of tonal structure on expectancy ratings and memory. Experiment 1 provides an initial test of these issues, using a set of simple folk melodies, and exploring the correlation between ratings of expectancy confirmations and subsequent memory for these melodies. Experiment 2 extends these findings, employing a convergent operation for the results of Experiment 1, and exploring memory confusions as a function of perceived expectancy.

Experiment 1: Relating expectancy and memory

In Experiment 1, the relation between expectancy and memory was assessed by having listeners rate melodies as to how well the endings of the melodies confirmed their expectations for what they thought would occur at that point. After providing such expectancy confirmation ratings, or "expectancy ratings" for short, listeners received a surprise recognition memory test in which they had to discriminate between the previously heard melodies and a similar set of new melodies. These ratings were then used to predict recognition memory accuracy, testing the two models just described. If highly expected melodies are more consistent with one's musical schemata, then expectancy should be correspondingly positively corre-

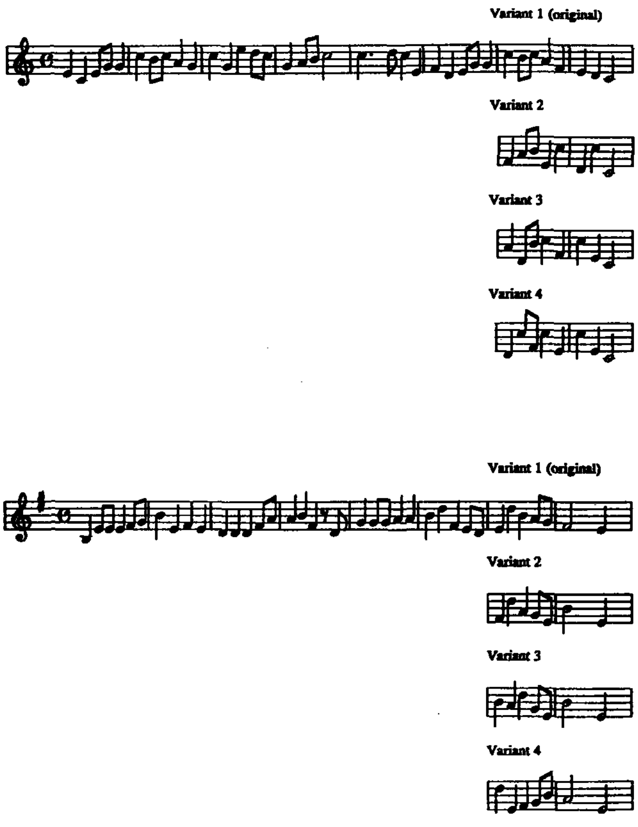

Figure 1. Two sample stimuli for Experiments 1 and 2. Shown are the beginnings of each melody (the 1st six measures), and the four different endings for each melody. Beginnings and endings played continuous make up the four variants of each melody.

lated with recognition accuracy. In contrast, if expectancy violations serve to segregate or highlight the items containing the violations, then low expectancy melodies (ones that contain such violations) will be better remembered than high expectancy melodies; accordingly, expectancy and memory will be negatively correlated.

METHOD

Participants

The final sample of participants consisted of 16 listeners; the data from 2 additional listeners were not used due to equipment problems. These listeners were all students at the University of Toronto at Scarborough (*M* age = 22.6 yrs), and either volunteered or received extra credit in a course in introductory psychology for participating. Although listeners were not recruited for any prior musical experience, on average they had received 2.1 yrs of formal musical training, had been making music for 3.9 yrs, were currently involved in music-making activities for 2.5 hrs/wk, and listened to music for 11.9 hrs/wk. All listeners reported normal hearing, and none reported prior familiarity with the stimuli of this experiment.

Stimulus Materials and Apparatus

Fourteen folk melodies were adapted as stimuli for this experiment. Each of these melodies was eight measures long, with a quarter-tone equaling 400 ms. Expectancies of these stimuli were manipulated by creating three variants of the original melody, produced by randomizing the order of the notes in the final two measures. Randomization was constrained in two ways. First, the final note of the original melody was retained as the final note in each variant, to eliminate any recency cue concerning the melody's identity, as well as to keep an equivalent sense of melodic/tonal closure in all the variants. Second, the rhythmic structure of the final measures of the original melody was retained in each variation. Thus, the randomization procedure altered the contour of these endings, and produced subtle changes in their tonal structure, while generally retaining the pitch content and global tonality of the melody, as well as holding temporal and rhythmic expectancies constant. The four possible variants for two stimulus melodies are shown in Figure 1; in this figure, variant 1 is the melody as originally written, and variants 2, 3, and 4 are the three randomized versions.

All stimuli were produced using a DX-7 synthesizer, under the control of an IBM compatible 286 Hz computer, using a Roland MPU-401 MIDI interface. The timbre in which all melodies were heard was harmonically complex, approximating the sound of a piano; further details of the harmonic structure of this timbre are available in Schmuckler (1989). All melodies were generated on-line by the DX-7 (controlled by the IBM-PC), and were amplified and presented to listeners via a Peavey KB-60 amplifier, set at a comfortable listening level.

Conditions and Procedure

This experiment involved two phases. In the "expectancy rating" phase, listeners provided expectancy confirmation ratings of the endings of 24 melodies (two variants for each of twelve melodies), with half the listeners ("group 1" listeners) rating variants 1 and 2 and the other half of the listeners ("group 2" listeners) rating variants 3 and 4. At the beginning of this phase, listeners were told they would hear a series of melodies, with some melodies very similar to one another, whereas others would differ. Listeners were asked to rate how well the final two measures of each melody fit their expectations for what was going to come at that point. Responses were made on a 7-point scale, with "1" representing a rating of "very unexpected" and "7" a rating of "very expected." Listeners made their rating by typing their response on the keyboard computer. Each listener heard these trials in a different random order. Prior to beginning these trials, listeners heard four practice trials (two variants of the two remaining melodies). The experimenter was present during these practice trials,

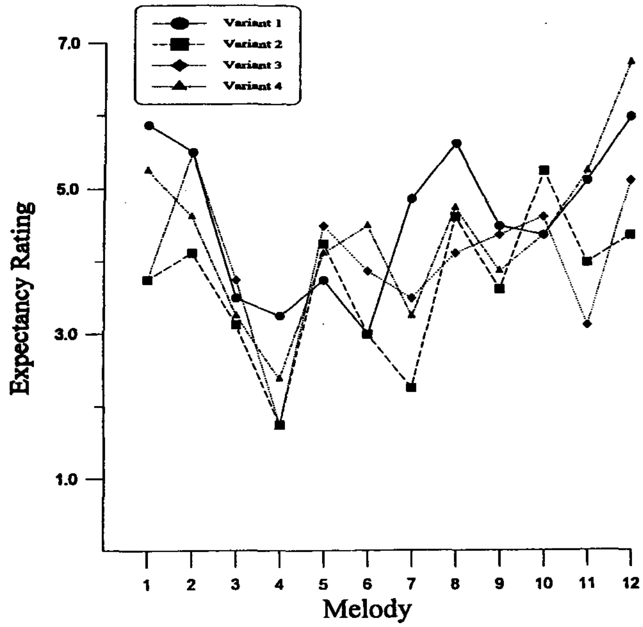

Figure 2. Mean listeners' expectancy ratings for four variants of the twelve stimulus melodies for Experiment 1.

assisting listeners in the use of the computer and rating scale, and answering any questions they might have had. The entire expectancy rating phase took anywhere from 10 - 20 minutes.

After completing the expectancy rating phase, listeners received a surprise "memory phase," in which they heard the 24 melodies of the expectancy rating phase, along with 24 new, unheard melodies; these new melodies were the two remaining variants of each of the 12 melodies. On each trial in this phase, listeners heard a melody, and indicated whether or not they had heard this melody during the previous phase. Listeners indicated their response using the computer keyboard, responding "1" if they felt that had heard this melody previously, and "0" if they had not heard this melody before. All listeners received these trials in a different random order. This memory phase lasted 20 - 30 minutes. After finishing the memory phase, listeners completed a questionnaire concerning their musical background, and were debriefed as to the purpose of this experiment.

RESULTS

Expectancy Ratings

Because the different variants were nested within group (group 1 listeners heard variants 1 and 2 whereas group 2 listeners heard variants 3 and 4), it is difficult to conduct an omnibus test that incorporates this nested factor and the different repeated measures factors in this design; accordingly, a more piecemeal analysis strategy was used. Specifically, a series of two-way analyses of variance (ANOVAs) were conducted, with the first factor the within-subjects variable of *melody* (melody 1, melody 2 ... melody 12), and the second factor one of the six possible paired comparisons of the different *variants* (e.g., variant 1 vs. variant 2, variant 1 vs. variant 3 ... variant 3 vs. variant 4). Given the design of this study, this factor was sometimes a within-subjects variable (variants 1 vs. 2, variants 3 vs. 4) and sometimes a between-subjects variable (variants 1 vs. 3, 1 vs. 4, 2 vs. 3, and 2 vs. 4). Across the analyses, there was a consistent main effect of melody (all p's $< .001$), suggesting that the endings of the melodies varied in the expectancies they engendered. In addition, there were occasional main effects of variant, as well as significant interactions between melody and variant. Figure 2 graphs the mean expectancy ratings for the four variants of the 12 melodies, and demonstrates a chaotic and non-systematic pattern of ratings. Although uninterpretable, this graph does reveal (1) good variation in expectancy ratings across melodies and variants, and (2) that no one variant consistently achieved higher ratings than the other variants. Both of these findings are important. Variation in expectancy ratings is important statistically to avoid range of restriction problems, as well as in indicating that the randomization procedure had its intended impact of manipulating expectancy ratings. Additionally, the fact that no single variant, and particularly variant 1 (the melody as originally written) always received the highest rating is important in that it indicates that although randomizing the final two measures produced melodies varying in expectancy judgments, listeners still heard these variants as musically "acceptable," despite the destruction of the serial order information of the original melody caused by this randomization. In this case, "acceptable" simply means that the ending was not, in any way, especially anomalous or unusual, with anomalies likely indicated by low expectancy ratings. The fact that none of these melodies appeared to be particularly anomalous is important in that a relation between expectancy and memory could have emerged from listeners simply discriminating anomalous (i.e., randomized) from acceptable (i.e., original) melodies, and simply remembering these anomalies without any effect of expectancy on memory *per se*. Thus, these analyses of the expectancy ratings provides a comforting manipulation check for this experiment.

Memory Performance

For each listener, the number of times they correctly recognized each melody as having been heard or not heard was calculated, and these scores were analysed in a three-way ANOVA, with the within-subjects factors of *melody* (melody 1 ... melody 12) and *variant* (variant 1 ... variant 4), and the between-subjects factor of *group* (group 1 vs.

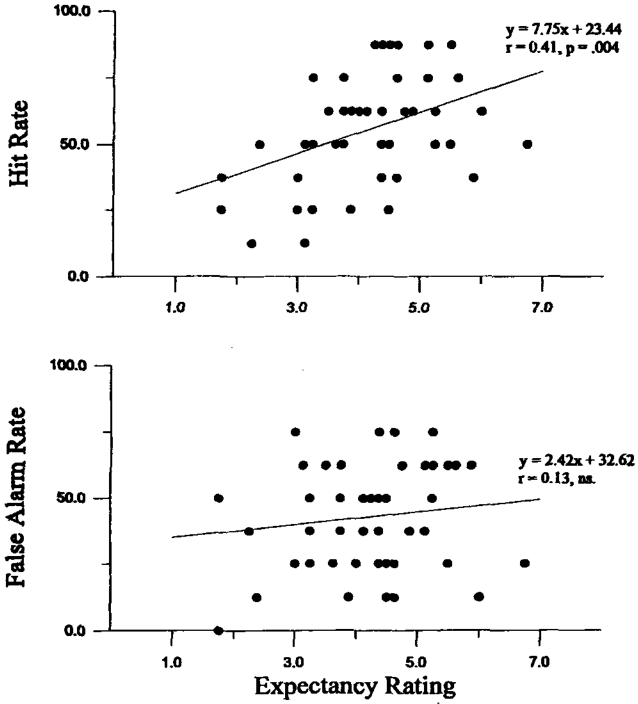

Figure 3. Memory performance graphed as a function of expectancy ratings for hit rates (percent correct recognition of previously heard melodies) and false alarm rates (1 - correct rejection of previously unheard melodies). Points in the scatterplots represent the four variants of each of the twelve melodies, and the line represents the regression line predicting memory performance from expectancy ratings.

group 2 listeners). Note that this analysis collapses over identifying a previously heard melody as familiar (in signal detection terms, a "hit") and identifying a previously unheard melody as novel (a "correct rejection"); analyses breaking down hits and correct rejections are presented subsequently. This ANOVA revealed two significant effects. First, and of primary importance, was the significant interaction between variant and melody, $F(33,462) = 1.55$, $MS_e = 0.23$, $p < .05$. Similar to the previously discussed concerns with the expectancy ratings, this variation is a statistical prerequisite for assessing whether perceived expectancy is related to memory. The second significant result was the three-way interaction between variant, melody, and group, $F(33,462) = 1.59$, $MS_e = 0.23$, $p < .05$; this effect was uninterpretable.

Memory Performance and Expectancy Ratings

The critical analysis in this experiment involved correlating the listener-produced expectancy ratings with their subsequent recognition of these melodies. One problem with this analysis is that a significant correlation might occur simply due to a bias by listeners to assume that they had heard highly expected melodies previously, regardless of whether or not these melodies had actually been presented. To control for this possibility, expectancy ratings were correlated separately with the averaged listeners' correct recognition rate for previously heard melodies (hits), and with the averaged listeners' false alarm rates for the new melodies (1 - correct rejections of unheard melodies). For hit rates, recognition memory was positively correlated with expectancy ratings, $r(46) = 0.41$, $p < .005$; this relationship is shown at the top of Figure 3. In contrast, there was no relation between false alarm rates and expectancy ratings, $r(46) = 0.13$, ns; this relation (or lack thereof) is shown at the bottom of Figure 3. Generally, these effects reveal that expectancy and memory are positively related, with this relation limited to only those melodies that were initially presented in the expectancy rating phase. One possibility is that having listeners rate the perceived expectancy of these melodies increases their awareness of this aspect, with a corresponding impact on memory. This idea will be further explored subsequently.

Memory Performance and Musical Tonality

A final series of analyses examined the effect of musical tonality on listeners' memory for these melodies. As already discussed, previous research has demonstrated that musical tonality has a significant impact on memory, with tonal melodies better remembered than atonal melodies (Cuddy et al., 1981; Cuddy et al.,, 1979; Francès, 1988). Although the melodies employed in this experiment were all tonal, the randomization procedure creating the different variants of each melody did produce differences between the variants in the total durations of the notes of these melodies. This difference is important given the evidence that relative differences in note durations within a piece of music provide information for musical key or tonality (Krumhansl, 1990; Krumhansl & Schmuckler, 1986; Schmuckler & Tomovski, 1997). This relation was exploited by Krumhansl and Schmuckler (1986; see Krumhansl, 1990) in their construction of a key-finding algorithm, which correlates the distribution of tone durations (or frequencies of occurrence) of musical passages with idealized "tonality vectors" for all of the different musical keys, based on the perceptual data of Krumhansl and Kessler (1983). This key-finding algorithm has proven robust in determining the tonality of musical passages varying in size (from a few notes to extended passages), and in musical style (Krumhansl, 1990; Schmuckler & Tomovski, 1997), as well as in characterizing differences in the tonal orientation of performed expectancy continuations (Schmuckler, 1990).

Given the relation between relative differences in note duration and perceived tonality, the fact that the randomization procedure produced differences in relative note durations for the endings of each melody means that the different variants potentially contain varying tonal implications. Such a difference is significant in that the tonality of the beginning (the first six measures) of each melody, which was common across the variants, may have differed from the tonality of the ending (the final two measures) of the melodies. Correspondingly, the greater the tonal difference between beginning and ending of the melody, the more tonally incoherent the melody sounds, resulting in decreased memory for that melody, relative to more coherent melodies.

The tonal implications of the beginnings and endings of each variant were calculated using the key-finding algorithm of Krumhansl and Schmuckler (1986; see Chiappe & Schmuckler, 1997; Krumhansl, 1990; Schmuckler, 1990; Schmuckler & Boltz, 1994; Schmuckler & Tomovski, 1997, for examples of this procedure). Specifically, the tonal implications of the beginnings and endings of each variant were mapped onto a location on Krumhansl and Kessler's (1982) map of musical key space, and the distance (in degrees) between each beginning and ending was calculated. This measure, which will be referred to as "tonal distance," represents the relative difference in implied tonality between the beginning and ending of each melody, with larger distances representing greater divergences.

Overall, there was a wide range of tonal distances for the different variants. Across all variants, the mean tonal distance was 57.7° degrees, with a range from 5.8° to 156.5°, and a standard deviation of 36.4°. For reference, the mean distance between a major key and its relative minor key (two highly related keys) is 49.6°, whereas the distance between two highly related major keys (e.g., C and G major) is 79.2°.

The effect of tonal distance on memory and expectancy was examined using multiple regression, predicting correct recognition scores from the expectancy ratings and tonal distance. These two factors significantly predicted recognition scores, $R(45) = 0.48$, $p < .003$, with both factors contributing to this relation, $\beta = 0.40$, $p < .004$, for expectancy ratings, and $\beta = -0.25$, $p < .06$, for tonal distances. The simple correlation between tonal distance and correct recognition was -0.27, $p = .06$, and there was no relation between the two predictors (expectancy ratings and tonal distance scores), $r = -0.04$, ns. Overall, this analysis indicates that as the tonal distance between the beginning and ending of a melody increased listeners' memory for that melody decreased. This result is in line with previous research (Cuddy et al., 1981; Cuddy et al., 1979; Francès, 1988) that suggests that tonally coherent information is better remembered than atonal music.

DISCUSSION

In answer to the primary question under investigation, listeners' expectations for melodies predicted memory for these melodies, with melodies in which endings fit with listeners' expectancies better remembered than melodies that did not fit listeners' expectancies. As originally suggested, this pattern of results coincides with the idea that schematically central material is better remembered than schematically peripheral information (Bartlett, 1939).

The most obvious mechanism for this result is that highly expected melodies are initially better encoded by listeners than are less expected melodies. In fact, many studies in musical cognition have observed encoding advantages for highly expected musical materials, in terms of reaction time to such information and accuracy in identifying such information (Bharucha & Stoeckig, 1986, 1987; Schmuckler & Boltz, 1994; Tekman & Bharucha, 1992). One consequence of such differences in processing is that information that is better encoded (i.e., high expectancy information) is processed more deeply than information that is encoded more shallowly (i.e., low expectancy information), with this difference in encoding ultimately resulting in corresponding differences in memory. Such a result would be consistent with the classic "levels of processing" account of human memory (e.g., Craik & Lockhart, 1972; Lockhart & Craik, 1990).

Along with listeners' judgments of expectancy confirmations, musical memory was also related to the tonal coherence of melodies, with a better match between the implied tonalities of the beginning and ending of a melody increasing memory. Although this relation between tonality and memory was modest, it is important to remember that the variation in implied tonality was produced by randomizing the final notes of each melody. Thus, the actual pitch content of the melody varied only slightly, resulting in changes in the implied tonality that were also relatively modest. Correspondingly, the beginnings and endings were generally musically related. Given that music typically contains tonal movement between related keys, it is possible that these variations were not, by and large, especially unusual or novel for listeners in terms of their tonal movement. Accordingly, there would be no relation between tonality and expectancy (a result actually observed), and a limited impact of tonality on memory. Given this context, it becomes remarkable that any influence of tonality on memory was seen at all.

Although these findings support the idea that expectancy influences memory, one concern with this study is that the procedure employed required listeners to both rate the expectedness of melodies, and then participate in a recognition memory test for these melodies. One reason this is an issue is that there is evidence that how one initially evaluates an event ultimately influences one's memory for that event (e.g., Dodson & Johnson, 1993; Hasher & Griffin, 1978; Lindsay & Johnson, 1989). Such an effect is consistent with the misleading-suggestion or misinformation effect (e.g., Lindsay & Johnson, 1989;

Loftus, Miller, & Burns, 1978), or the verbal overshadowing effect (Dodson, Johnson, & Schooler, 1997; Fallshore & Schooler, 1995; Schooler & Engstler-Schooler, 1990). In the current situation, having listeners rate expectancy confirmations might have drawn attention to this aspect of the melodies, thereby producing a relation between expectancy and memory that might not otherwise have occurred. This possibility is supported by the finding that the relation between expectancy and memory was limited to melodies that listeners had heard during the expectancy rating phase. One goal of Experiment 2 was to further explore the relation between judgments of expectancy confirmations and memory using a task that is not potentially influenced by prior expectancy judgments.

Experiment 2: Study-test recognition memory for melodies

Experiment 2 employed a converging operation to Experiment 1, testing the influence of expectancy on memory using a procedure in which listeners heard an initial study melody followed by a set of test melodies, and then indicating which of the test melodies was the same as the initial study melody. Manipulation of the perceived expectancy of study and test melodies was accomplished using the expectancy ratings from Experiment 1 to categorize the stimuli into groups of high, medium, or low expectancy. Assuming that expectancy is positively related to memory, high expectancy melodies will be remembered better than medium expectancy melodies, which in turn will be remembered better than low expectancy melodies.

A study-test recognition memory procedure has the added advantage that it produces a memory confusion matrix for the different variants of each melody, thereby allowing for a test of the prediction that memory confusions will be asymmetric, depending on their level of expectancy. As already suggested, one possible asymmetry would be that low expectancy study melodies will be often confused with high expectancy test melodies, whereas high expectancy study melodies will be rarely confused with low expectancy test melodies.

METHOD

Subjects

The final sample of listeners included 16 students (*M* age = 22.2 yrs) from the University of Toronto at Scarborough, who received extra credit in an introductory psychology course for their participation. One additional subject began this experiment but, finding the experimental procedure too onerous, refused to continue the study after the practice trials. Although not recruited on the basis of prior musical background, listeners had, on average, 5.8 yrs of formal musical training, and had been playing music for 9.2 yrs. Listeners were currently engaged in musical activities for 2.2 hrs/wk, and listened to music for 15.0 hrs/wk.

Stimuli and experimental apparatus

The stimuli for this experiment consisted of the same four variants of the melodies used in Experiment 1. Each variant of a given melody was categorized into one of three groups, based on the expectancy ratings of Experiment 1. The highest rated variant of each melody was classified as the "high expectancy" melody, the lowest rated variant was classified as the "low expectancy" melody, and the remaining two variants were classified as "medium expectancy." In situations in which two variants received equivalently high or low ratings, both variants were considered high (or low) expectancy melodies, respectively. This study used the same experimental apparatus as Experiment 1.

Procedure

All listeners participated in a study-test recognition memory paradigm, with each trial consisting of a single study item followed by four test items. At the beginning of each trial, listeners heard the study melody; after this melody finished, the four test melodies were played consecutively. The computer provided the appropriate labels for these stimuli (e.g., "study melody," "test melody 1"), simultaneous with the presentation of the melodies. After the fourth test melody, listeners had to identify which of the test melodies was the same as the originally heard study melody. After entering their response using the computer keyboard, the next trial began automatically. Listeners received four practice trials prior to beginning the block of experimental trials, using different melodies than those of the experimental trials. There were 48 experimental trials in all, with each variant of each melody appearing as the study melody once. For all listeners, the order of the test melodies on each trial was randomized, as was the order of the experimental trials across the block of trials. Subsequent to the experimental trials, listeners completed a questionnaire concerning their musical background, and they were debriefed as to the purpose of this experiment. The entire experiment lasted approximately 60 minutes.

RESULTS

Correct recognition

For each listener, memory performance was assessed by coding correct melody identification as "1" and incorrect identification as "0," and analysing these scores in a two-way ANOVA, with the within-subjects factors of *Expectancy Rank* (high vs. medium vs. low) and *Melody* (melody 1 through melody 12). Although there was no main effect for melody, $F(11,165) = 0.8$, $MS_e = 0.18$, ns., there was a significant main effect of expectancy rank, $F(3,20) = 13.65$, $MS_e = 0.14$, $p < .001$. The mean percent recognition scores demonstrate the best memory for high expectancy melodies ($M = 60.0\%$, $SE = 3.5$) , followed by low expectancy melodies ($M = 42.2\%$, $SE = 3.2$), and finally by medium expectancy melodies ($M = 36.5\%$, $SE = 3.0$). Post-hoc comparisons on this effect, using Bonferroni corrections, revealed that the recognition of high expectancy melodies was superior to both medium [$F(1,15) = 25.3$, $MS_e = 0.01$, $p < .001$] and low [$F(1,15) = 11.24$, $MS_e = 0.01$, $p < .02$] expectancy melodies. In contrast, there was no difference between medium and low expectancy melodies [$F(1,15) = 5.11$] after correcting for the multiple comparisons.

The two-way interaction between expectancy rank and melody was also significant, $F(22,330) = 2.65$, $MS_e = 0.18$, $p < .001$. Inspection of this interaction revealed that the high expectancy variants of each melody were recognized best, receiving the highest recognition score for 9 of the 12 melodies. In contrast, medium and low expectancy melodies were equivocal in the ranking of their recognition scores, with medium expectancy variants better recognized than low expectancy variants about half of the time. This interaction, then, represents variation in the relative recognition of low and medium expectancy melodies.

Memory confusions

To examine memory confusions, the number of times each incorrect test melody was confused with the study melody was tabulated (removing the diagonal, which represents correct recognition) and averaged across listeners to produce a memory confusion matrix for each melody. These individual memory confusion matrices were then aggregated across the different melodies to produce a single confusion matrix. The initial analysis of this confusion matrix involved comparing the top and bottom half-matrices to assess whether or not this matrix was asymmetric. This issue of asymmetry is critical given the earlier prediction that high expectancy test melodies would be often confused with low expectancy study melodies, but not vice versa. To test symmetry, the top and bottom halves of the confusion matrices were correlated. This analysis failed to reveal a significant relation between the half-matrices, $r(70) = -0.10$, ns., indicating that the confusions matrices were asymmetric. So, for example, the probability of confusing comparison melody M1 with study melody M2 was not equivalent to the probability of a confusion when M2 was the comparison melody and M1 was the study melody; the exact nature of this asymmetry is the subject of subsequent analysis.

To further explore these memory confusions, the confusion matrices were compared with the expectancy ratings and tonal distance measures of Experiment 1. For expectancy ratings, "signed" differences scores were calculated by subtracting the rating for each test variant from the rating for the actual study variant (ignoring, of course, the case in which the test variant was the study variant). Thus, positive numbers indicate that the study variant was more expected than the test variant, whereas negative numbers imply that the study variant was less expected than the given test variant. In addition, "absolute value" differences scores were calculated; these scores reflect the magnitude of the expectancy difference between study and test variant, devoid of whether study or test was more expected.

The signed and absolute value expectancy rating difference score matrices for each melody were aggregated, and then correlated with the memory confusion matrices. There was a significant correlation for the signed expectancy rating difference score, $r(142) = -0.29$, $p < .001$, but no correlation for the absolute value expectancy rating difference score, $r(142) = -0.07$, ns. The significant negative correlation for the signed differences indicates that memory confusions increased as the expectancy rating for the test melody surpassed that of the study melody. The lack of an effect for the absolute value differences implies that it is not simply a discrepancy in perceived expectancy *per se* that relates to memory confusions.[1]

The final step in this analysis compared the memory confusion matrix with tonality differences between study and test variants, again computing tonal space distances using the key-finding algorithm of Krumhansl and Schmuckler (1986). Two tonal space distance measures were derived. The first computed tonal space positions based on duration profiles for each variant in its entirety, whereas the second employed duration profiles derived exclusively from the endings of each variant. In contrast to the expectancy rating analysis, there was no significant correlation between the memory confusion matrix and the tonal space distance matrices for either measure, with $r(142) = 0.07$ for distances based on each variant in its entirety, and $r(142) = 0.08$ for distances based on the endings of each variant. Although initially counterintuitive, this lack of an effect makes sense when one realizes that the tonal space distance measure is inherently symmetric, and as such, should not be sensitive to asym-

1 Calculating a difference score is not the only possible measure of variation in expectancy ratings; a related measure would be to compute ratio scores. In fact, comparisons of ratio scores with the memory confusion matrix revealed virtually equivalent effects to those of the differences scores reported in the text. In a different vein, one could compute either difference or ratio scores employing the rank orderings of the ratings, rather than the ratings themselves (high expectancy = 2, medium expectancy = 1, low expectancy = 0). Analyses employing expectancy rankings revealed comparable effects to those using the expectancy ratings.

metric memory confusions. Supporting this general finding, there were no significant intercorrelations amongst the expectancy rating and the tonal space distance matrices.

DISCUSSION

The purpose of Experiment 2 was to provide a convergent measure for Experiment 1, examining the impact of expectancy on memory in a context devoid of any explicit or implicit reference to expectancy. Additionally, this study explored errors in recognition, looking for asymmetrical memory confusions between pairs of melodies as a function of differential perceived expectancy. Overall, these goals were achieved, with a demonstration of expectancy effects on both recognition memory and on memory confusions.

Unfortunately, although there were observable influences of expectancy on memory, this effect was restricted to a distinction between high expectancy melodies on the one hand, and all other (i.e., medium and low expectancy) melodies on the other hand. Although potentially worrisome, other studies on musical expectancy have reported somewhat similar results. Schmuckler (1989, Experiment 2) found that listeners' ratings of harmonic continuations produced reliable differences primarily when comparing high expectancy events (based on music-theoretic descriptions of harmonic relations) to medium and low expectancy events; in contrast, there was little distinction between ratings of medium and low expectancy events. Similarly, Schmuckler and Boltz (1994) observed that the impact of rhythmic context on expectancy ratings and the speed of processing of harmonic events was primarily restricted to high expectancy events. Finally, Bharucha's studies investigating the speed of processing and accuracy of encoding of musical events have tended to restrict comparisons to relatively diverse, high and low expectancy events (Bharucha & Stoeckig, 1986, 1987; Tekman & Bharucha, 1992); recent research (Schmuckler, 1997a) has begun to examine whether more subtle differences in perceived harmonic relatedness (e.g., differences between intermediately related chords) can be captured by such measures. Accordingly, it may not be that surprising to find only a relatively gross effect of expectancy on memory.

In addition to this effect, it is also possible that calling attention to the actual level of expectancy confirmation versus disconfirmation, as done in Experiment 1, ultimately influences memory for melodic information; this finding is consistent with the misinformation (e.g., Loftus et al., 1978) or verbal overshadowing effect (e.g., Schooler & Engstler-Schooler, 1990), described earlier. Two points are important in this regard. First, although listeners in this study did not provide explicit expectancy ratings, there remained a relation between expectancy and memory, albeit at a gross level. Thus, calling attention to expectancy confirmations appears to heighten or strengthen a more general relation between expectancy and memory. Second, calling attention to expectancy confirmations primarily affects melodies of low expectancy, as opposed to high expectancy. Thus, having listeners make expectancy judgments may make them more aware of more minor expectancy differences between melodies, distinctions that are lost without noting them explicitly.

General Discussion

The current studies provide compelling evidence of the impact of expectancy formation on subsequent memory for musical events. Across two experiments, listeners' recognition memory for melodies was positively related to perceived expectancy, with melodies ending in a highly expected fashion better remembered than melodies that ended in a less anticipated way. Furthermore, listeners' displayed asymmetric memory confusions, such that melodies of high expectancy were confused more often with low expectancy melodies than the reverse.

Why is it that highly expected information was better remembered than less expected information? The explanation being most strongly argued here stems from the classic finding that schematically central information is better remembered than more peripheral information (e.g., Bartlett, 1932). In this vein, high expectancy information is seen as more central to one's musical schema, compared with medium and low expectancy information, which is more peripheral to one's schemata. This characterization of the relation between expectancy and memory also explains the observed memory asymmetries as a function of perceived expectancy by positing that memory for schematically peripheral or "irregular" information ultimately becomes distorted towards more central, expected information.

One question arising from this explanation concerns the processes by which such highly expected musical schemata are formed. One answer to this question is that high expectancy musical schema develop through processes of prototype abstraction, similar to the ideas expressed in the classic work of Posner and Keele (1968, 1970; Posner, Goldsmith, & Welton, 1967). In this case, listeners abstract the more expected, prototypic pattern of a melody from hearing deviations of this prototype; this possibility is being examined in current work.

Despite the rather intuitive appeal of this explanation, an alternative model involving the idea that highly unexpected or unusual events would lead to better memory for melodies was also proposed. This model was based on the well-known von Restorff effect (von Restorff, 1933; see Wallace, 1965) in which items that are incongruous with a homogenous background are better remembered than items not isolated from the background. Although this model did not account for the results of these experiments, it is worth noting that in Experiment 2, whereas high expectancy melodies were best recognized, there was a tendency for low expectancy melodies to be better remembered than the medium expectancy melodies. If this trend is taken seriously, this raises the possibility that both models might play a role in characterizing the relation between expectancy and memory.

As limited support for this idea, it should be pointed out that the current situation may not have provided an ideal assessment of the possibility of von Restorff-like effects in musical memory. The von Restorff effect usually occurs in situations in which a particular item is incongruous with its background. In contrast, it is not totally correct to conceptualize the unexpected melodies of these studies as being highly incongruous. These melodies were, after all, tonally and rhythmically coherent. It therefore remains possible that a von Restorff effect might be operative in musical contexts in which the unexpected musical materials are clearly more deviant, or stand out more, from the expected background. If true, this suggests that the relation between expectancy and memory might be best characterized via a U-shaped function, with both highly expected and highly unexpected events leading to good memory. Although speculative, this possibility represents an intriguing avenue for future research.

Although recognition memory was predictable from perceived expectancy and musical tonality, these factors did not account for a huge percent of the variance in these experiments. This observation raises at least two questions: (1) why this effect might have been modest, and (2) what other factors might account for memory recognition? In response to the first question, although the melodies in this experiment varied in perceived expectancy and implied tonality, they did not, as already discussed, represent a particularly large range of deviation for either factor in any absolute way. These somewhat limited ranges stem from the procedure used to produce the different variants of the melodies, which retained basic parameters such as the global tonal/pitch content of the melodies as well as the rhythmic structure of the original. Wider variation in these dimensions might have generated both greater divergences in implied tonality, as well as more diverse perceptions of the expectedness of these melodies, and thereby potentially increasing the predictive power of either or both factors.

In response to the second question, research in musical perception and memory suggests another obvious factor that, along with expectancy and tonality, will influence memory for melodies — that of melodic contour. Contour, which refers to the general pattern of rises and falls within a melody, has long been recognized as a central component of musical cognition (e.g., Dowling, 1978; Dowling & Harwood, 1986), and has earned a prominent place in theories of musical processing (see Dowling, 1994, for an introduction). Somewhat obviously, one way in which predictions of recognition memory might be enhanced would be to incorporate a factor of melodic contour.

One drawback to this idea is that there are few formal models of melodic contour that make possible characterizations of such influences (see Schmuckler, 1997b, for a discussion). Generally, research in this area has employed relatively gross characterizations of contour (e.g., same vs. different), without providing any detailed metric for quantifying a melody's contour, or the level of contour similarity between melodies, and so on. Recently, Schmuckler (1997b) has developed a model of contour based on fourier analyses of melodies, with similarity defined by correspondences between the amplitude and/or phase spectra of the fourier analyses of melodies. This model successfully predicted derived similarity judgments of both 20th century, atonal melodies, as well as simplistic tonal melodies. Within the current context, this model can potentially characterize the internal coherence of a melody's contour (e.g., is the contour of the beginning and ending of a melody related), as well as providing a metric for predicting memory confusions (i.e., increased contour similarity leads to increased memory confusions). Current research on this model is exploring these implications.

Although the role of expectancy in memory has been examined within the domain of musical processing, it should be recognized that much of this work has broader implications for memory research. One such generalization involves the status of the "schema" and von Restorff approaches as general models of memory; this issue has already been discussed. A second issue concerns the general status of the concept of "expectancy" in memory research in particular, and psychological thought as a whole. The concept of expectancy, or the related term "preparatory set," has a checkered history in psychology. For example, although expectancy has been a topic of interest in learning theories of animal and human behaviour (e.g., Gibson, 1941; Haber, 1966; MacQuorquodale & Meehl, 1953; Meehl & MacQuorquodale, 1951; Mowrer, 1938, 1941; Mowrer, Raymond, & Bliss, 1940; Tolman, 1932), it has also come under attack from both behaviourist and information processing approaches. Correspondingly, expectancy has not explicitly played much of a role in more current theories of human memory.

Expectancy-like effects, however, are difficult to ignore in research on memory; indeed, the growing concern with the impact of "context" in more recent memory models (e.g., Dalton, 1993; Murnane & Phelps, 1993, 1994, 1995) provides an obvious vehicle by which expectancy-based processes are being incorporated into current theories of human memory. In this case, context plays a role by affording a framework through which observers can better integrate and elaborate the to-be-remembered information, thereby increasing the depth of processing of such information, reducing memory load for information, as well as providing a means for anticipating upcoming information. Accordingly, the concept of expectancy is proving hard to ignore. Research in musical cognition on the factors underlying expectancy generation, the impact of expectancy generation on the perception of and response to musical patterns, and one's subsequent memory for such information as a function of perceived expectancy, then, provides an illuminating microcosm for cognitive research, having implications for our view of human memory quite generally.

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Sommaire

La génération d'attentes a été reconnue comme un facteur central dans les perceptions de ceux qui écoutent la musique et les analyses psychologiques et théoriques sur la musique continuent de lui accorder une grande importance. Étant donné cet intérêt, il n'est pas étonnant que l'on ait constaté que les attentes jouent un rôle essentiel dans les jugements des auditeurs, le traitement et l'exécution de l'information musicale.

La recherche sur les attentes n'a cependant pas accordé beaucoup d'attention à l'influence des attentes sur la mémoire de la musique. Un des modèles de ce type de relation prévoit que les attentes et la mémoire seront reliées positivement et que l'information pour laquelle les attentes sont élevées sera mieux retenue que l'information pour laquelle les attentes sont faibles. Dans un tel cas, les éléments pour lesquels les attentes sont élevées correspondent mieux au schéma musical d'une personne. Elle peut donc mieux les retenir que ceux pour lesquels les attentes sont faibles et qui feraient davantage partie d'un schéma périphérique. Ce modèle prévoit également des confusions dans la mémoire asymétrique entre l'information pour laquelle les attentes sont élevées et celle pour laquelle elles sont faibles et dont les événements inattendus sont plus souvent confondus avec les événements attendus que l'inverse. Un second modèle de relation entre les attentes et la mémoire montre que les événements inattendus seront mieux retenus que les événements attendus parce qu'ils peuvent être isolés ou "ressortir" du contexte. La mémoire et les attentes seraient donc reliées négativement.

Deux expériences nous ont permis d'étudier l'influence des attentes musicales sur la mémoire. Lors de l'Expérience 1, les auditeurs écoutaient deux variantes de 12 mélodies folkloriques. La variante était une modification au hasard du ton des deux dernières mesures de chacune des mélodies. Les auditeurs ont souligné que la fin de chacune des mélodies correspondait particulièrement bien à leurs attentes, c'est-à-dire à ce qu'ils croyaient qui allait se produire à ce moment. Après avoir évalué la confirmation de leurs attentes, les auditeurs ont subi un test surprise de mémoire de reconnaissance dans lequel ils devaient faire la différence entre les mélodies déjà entendues et un nouvel ensemble de variantes semblable au précédent. La précision de la mémoire de reconnaissance correspondait positivement aux évaluations des attentes, ce qui suggère que les mélodies pour lesquelles les attentes étaient très élevées étaient mieux retenues que celles pour lesquelles les attentes étaient faibles. De plus, une mesure de la cohérence du ton des différentes variantes de chacune des mélodies permettait de prévoir les indices de la mémoire puisque les variantes dont les tons étaient semblables étaient plus faciles à retenir que celles dont les tons variaient.

L'expérience 2 constituait une opération convergente par rapport à l'expérience 1. Les auditeurs écoutaient une première mélodie d'étude suivie d'un ensemble de mélodies témoins, puis indiquaient laquelle des mélodies témoins correspondait à la première mélodie. Les attentes avaient été manipulées à l'aide des jugements de confirmation de l'expérience précédente. En général, l'examen de la précision de la mémoire a confirmé la structure observée au cours de l'expérience 1 soit que les mélodies pour lesquelles les attentes étaient élevées étaient mieux retenues que celles pour lesquelles les attentes étaient faibles ou moyennes, bien que le niveau de précision ait été le même dans le cas des attentes moyennes et faibles. L'examen des choix incorrects a permis de découvrir des confusions dans la mémoire asymétrique; les mélodies témoins dont les attentes étaient élevées étant souvent confondues avec les mélodies d'étude pour lesquelles les attentes étaient faibles, tandis que les mélodies témoins dont les attentes étaient faibles étaient elles, rarement confondues avec les mélodies d'étude pour lesquelles les attentes étaient élevées. Dans l'ensemble, ces résultats suggèrent que, par rapport à l'information pour laquelle les attentes sont moyennes ou faibles, l'information pour laquelle les attentes sont élevées est plus centrale dans le schéma musical et que ce type d'information est traité plus en profondeur et donc, mieux retenu. De plus, l'information en périphérie du schéma se déformait par rapport à l'information attendue plus centrale. Les confusions de mémoire étaient donc asymétriques.