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The Feeling of Music Past: How Listeners Remember Musical Affect

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This study was conducted to determine how listeners derive global evaluations of past musical durations from moment-to-moment experience. Participants produced moment-to-moment affective intensity ratings by pressing a pressure-sensitive button while listening to various selections. They later reported the remembered affective intensity of each example. The data suggest that the assumption that remembered affect equals the sum of all momentary affects fundamentally misrepresents how listeners encode and label past affective experiences. The duration of particular rather than uniform episodes contributes minimally to remembered affect (duration neglect). Listeners rely on the peak of affective intensity during a selection, the last moment, and moments that are more emotionally intense than immediately previous moments to determine postperformance ratings. The peak proves to be the strongest predictor of remembered affect. We derive a formula that takes moment-to-moment experience as input and predicts how listeners will remember musical affect. The formula is a better predictor of postperformance affect than any other on-line characteristic considered. Last, the utility of the formula is demonstrated through a brief examination of compositional decisions in a string quartet movement by Borodin and one typical format of four-movement symphonies from the classical period.

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MUSICAL experience takes time. Be it 4 min 33 sec of silence (Cage) or 18 hr of the *Ring* cycle (Wagner), the felt affect varies from moment to moment in both intensity and quality. Despite momentary variations in affect, listeners form a global evaluation of a piece after it has ended, reducing its complexity and subtlety of feeling down to perhaps a single

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word (e.g., sad) or a single number (e.g., three stars out of five). This article explores how listeners remember musical affect—how they evaluate a past music-affective experience. Previous research (discussed later) indicates that there is a complex and nonlinear relationship between experienced pleasure and remembered pleasure. Further, it is the memory of musical experience that determines whether we choose to repeat the experience in the future, whether we recommend it to others, and how we evaluate the past quality of our musical lives. Hence, a study of remembered affect and how it derives from moment-to-moment affect is a critical component of an overall understanding of musical affect.

Many experimenters have recorded on-line experiences of music by asking participants to manipulate a dial, slider, or pressure-sensitive button to represent increases or decreases in some facet of moment-to-moment experience—affect, aesthetic preference, and so forth (Clynes, 1977, 1980; Fredrickson, 1995; Gregory, 1989; Krumhansl, 1996; Madsen, 1990, 1996; Madsen, Byrnes, Capperella-Sheldon, & Brittin, 1993; Madsen, Capperella-Sheldon, & Johnson, 1991; Madsen & Fredrickson, 1993; Nielsen, 1983; Rozin, 2000; Waterman, 1996). With sufficient training, participants learn to use the device without wasting great amounts of attention on the task. Thus they can record their responses and still attend to the music. The rich data that result from such experimentation shed much light on how music elicits, for example, emotional responses as a piece is unfolding. However, what the aforementioned studies do not address is how a listener's moment-to-moment experience becomes an affective memory, that is, how memory of a past emotional experience with music systematically represents and perhaps misrepresents that experience.

Other important studies regarding emotion and music report on data representing memories of affective experience in the form of postperformance ratings of specific emotions, arousal, and emotional intensity (see, e.g., Gundlach, 1935; Imberty, 1979; Rigg, 1937; Watson, 1942; Wedin, 1972). In contrast to the research on moment-to-moment experience, these studies provide insight into what listeners are left with after a piece of music has ended, but they do not offer any explanation of how these memories of musical experience derive from moment-to-moment variables. How does a listener's designation of a piece as "sad" or "intense" emerge from a continually changing experience that may last several hours?

One study does consider the relationship between a listener's moment-to-moment experience of music and memories of that music (Sloboda & Lehmann, 2001). In their attempt to better understand how specific performance variables affect listeners's emotional responses, Sloboda and Lehmann record moment-to-moment emotionality ratings as well as postperformance evaluations on a scale of "inexpressiveness-expressiveness." They found that "the climax of the piece correlated somewhat higher with the postperformance ratings than the antecedent sections and the coda" (p. 98) and that the mean of moment-to-moment ratings correlated with the postperformance scale at .50 ($p <. 001$). The authors conclude that because the mean can account for only about 25% of the variance, "the cognitive processes that occur after the end of a performance to yield a single judgment must be extremely complex" (p. 110).

Just as music psychologists have tended to concentrate on either moment-to-moment experience of emotion or memory of emotion, music theorists have largely focused on either the formation of musical structure and affect (e.g., Hasty, 1997; Meyer, 1956, 1973; Narmour, 1984, 1990, 1991, 1992, 1996, 1999) or the final state of a listener's experience (e.g., Lerdahl & Jackendoff, 1983). Theories that attempt to capture how listeners derive musical relationships, aesthetic responses, and affective reactions in the moment—what are often called *diachronic* models—do not consider the erosive or distorting force of memory. L. Meyer (personal communication, 1999) most often analyzes short passages of music that contain only 7 ± 2 events and hence could be contained in short-term memory. Thus he does not ignore memory in his analyses, but rather he intentionally avoids the need to deal with it. Theories that represent remembered structure and affect—what are called *synchronic* models—do not show how the final state of a listener's experience came to be.

The need for a study of how remembered affect derives from moment-to-moment affect becomes more apparent when we consider some of the assumptions of musical scholarship. For example, in his defense and elaboration of Gurney's (1880) emphasis of moment-to-moment experience, Jerrold Levinson writes:

> Now the core experience of a piece of music is a matter of how it seems at each point—a matter of the character and quality of each part as it comes. The core experience of a piece of music is decidedly not of how it is as a whole, or even of how it is in large portions, since one never has the whole, or large portions of the whole, except in abstract contemplation. Because experience of the parts in sequence is crucial, and because experience of the whole or large portions of it is not, *the value of the total experience—and thus, ultimately, of the piece of music—is to a good approximation just the sum of the values of the individual experiences of parts.* (Levinson 1997, pp. 159–160, italics ours)

We do not aim to defend or refute Levinson's and Gurney's position concerning the insignificance of abstract contemplation of musical wholes for musical experience and value. Rather, we wish to challenge the assumption that a musical experience is "to a good approximation just the sum of the values of the individual experiences of parts." No evidence exists to support Levinson's claim, and ample data suggest that, for certain nonmusical experiences, remembered affect does not derive from simple summations of moment-to-moment affects.

Recent research in decision-making and utility theory, under the leadership of Daniel Kahneman, offers insight into how to explore the relationship between remembered affect and moment-to-moment affect and what we might expect to discover. Although it does not involve music and deals primarily with pain rather than with affective intensity, this series of experiments provides the methodological basis for the current study. It is relevant because the experimental design entails both on-line and retrospective ratings of temporal experiences. As we will show, statistical comparisons reveal how present becomes past and how past misrepresents present.

In one version of this design, participants evaluated emotional films (Fredrickson & Kahneman, 1993). They watched plotless and rather uniform clips of images such as ocean waves and provided moment-to-moment pleasantness or unpleasantness ratings and global evaluations after each clip. Statistical analysis showed that the best predictor for remembered affect of positive films was neither the sum of moment-to-moment ratings nor the average of these ratings but instead the sum of (1) the highest of the moment-to-moment affect ratings (i.e., the affective peak) during the film and (2) the momentary affect rating at the end of the film. This is what the authors refer to as the *peak-end rule.* For negative films, the affective peak rating emerged as the best predictor of remembered affect, a finding that does not hold for other negative stimuli such as pain induced by medical procedures, as will be discussed later. The importance of the peak in retrospective evaluations confirms results from studies that show that greater affective intensity leads to stronger memory encoding (Gold, 1987; Hall, Gonder-Frederick, Chewning, Silveira, & Gold, 1989; Manning, Hall, & Gold, 1990) and aids long-term retention of information (Dutta & Kanungo, 1975; Heuer & Reisberg, 1990). In both the positive and negative cases, the length of the film clip did not affect retrospective ratings. Participants retrospectively rated 30 s of ocean waves the same as 90 s of ocean waves. That is, participants exhibited *duration neglect* in their determinations of remembered affect.

The ramifications of duration neglect are significant and perhaps surprising. Retrospective evaluations of affective episodes do not derive from simple summations of moment-to-moment affects. Thirty seconds of pleasant ocean waves and 90 s of the same produce the same remembered affect despite the fact that the longer version entails 1 min of extra pleasantness. As the authors of this study state, this violates a rule of "temporal monotonicity" (Fredrickson & Kahneman, 1993). Although it is logical to believe that adding moments of pleasantness makes an experience better and adding pain makes it worse, the data from this experiment suggest that this is not necessarily so.

To further explore the role of duration neglect, another experiment tested on-line and remembered pain induced by immersion of the arm in ice water (Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993). Each participant provided on-line and retrospective ratings of two separate experiences. In one trial, participants immersed a hand in water at 14°C for 60 s. In the other trial, they immersed the other hand in water at 14°C for 60 s and then kept the hand in the water for 30 s more as the temperature was raised gradually to 15°C. If, as the experimenters hypothesized, the peak-end rule predicts remembered affect (as it did for positive film clips), then participants would retrospectively prefer to repeat the longer trial despite the fact that it involved more total experience of pain because it ended with a higher temperature and hence lower pain than did the shorter trial. In fact, most participants chose to repeat the long trial because in their memories it induced less pain. Again duration did not emerge as an important factor in participants' determinations of remembered affect.

Redelmeier and Kahneman (1996) provided a third test of duration neglect and the peak-end rule, testing momentary and remembered pain of colonoscopy patients. As with participants in the previous experiments, the patients' remembered pain correlated most significantly with the combination of peak and end ratings and did not correlate at all with duration. Their memories of the procedure derived principally from the most painful moment and the pain at the end of the experience but did not depend on how long the experience was.

Kahneman, Wakker, and Sarin (1997) report on another study involving patients undergoing colonoscopy. For half the patients, the surgical instrument was left in place for about 1 min after the medical procedure was finished. The added portion of the experience was uncomfortable but less so than the actual procedure. Thus, as with the longer trial in the ice-water experiment, these participants experienced more total pain but the entire episode ended with a lower pain value than those who got the shorter trial. Again, participants' retrospective evaluations of the procedure demonstrated the peak-end rule and duration neglect. In this case, prolonging the episode actually lessened the patients' remembered pain.

Going beyond the peak-end rule, several experiments show the importance of other moment-to-moment characteristics. Hsee and Abelson (1991) suggest that the positive or negative slope of change within an experience is perhaps the overriding factor for evaluating past episodes. Loewenstein and Prelec (1993) show that participants quite naturally prefer declining (rather than increasing) sequences of pain. In their exploration of advertisements, Baumgartner, Sujan, and Padgett (1997) find that participants prefer commercials that have high momentary emotional peaks, end positively, and generally increase in positive affect from moment to moment. Similarly, Ariely (1998) finds that peak, end, and slope all influence retrospective evaluations of pain. Interestingly, his data suggest that duration neglect operates for homogeneous stimuli (e.g., ice water at one temperature) but not for heterogeneous stimuli (e.g., ice water with varying temperature or a series of interrupted episodes). This would seem to predict that duration neglect would be less of a factor for most musical experiences than for ocean waves, for example. Duration neglect would presumably be more prominent for relatively homogeneous styles such as minimalism and new age music as opposed to relatively heterogeneous styles such as baroque music and bebop.

Research on remembered pleasure for meals strongly confirms the idea of duration neglect (Rode, Rozin, & Durlach, 2004). Extending the duration of the favored component of a meal has no enhancing effect on remembered pleasure of the meal. On the other hand, there were minimal if any effects for peak or end on the retrospective evaluation of meals.

From the work just described, we can form several hypotheses about how listeners might calculate remembered affect for a phrase, piece, or entire concert on the basis of how they feel from moment to moment. That is, the research on colonoscopies, ice water, meals, and so on offer some possibilities for predicting how a listener's moment-to-moment experience of affective intensity (i.e., the degree of felt affect) will shape that experience into an encapsulated memory.

Hypothesis 1. *Duration neglect:* The length of a piece of music should contribute minimally to remembered affect. However, following Ariely (1998), the heterogeneous structure of music over time might increase the contribution of duration to remembered affect.

Hypothesis 2. *Peak significance:* Following Fredrickson and Kahneman (1993), Kahneman et al. (1993), Redelmeier and Kahneman (1996), and Kahneman, Wakker, and Sarin (1997), the peak of momentary affective intensity should disproportionately influence remembered affect.

Hypothesis 3. *End significance:* Following Fredrickson and Kahneman, (1993), Kahneman et al. (1993, 1997), and Redelmeier and Kahneman (1996), the last momentary affective intensity should disproportionately influence retrospective evaluations of affect.

Hypothesis 4. *Slope significance:* Following Hsee and Abelson (1991), Loewenstein and Prelec (1993), Baumgartner et al. (1997), and Ariely (1998), the slope of moment-to-moment intensity experience should influence remembered intensity in some significant way. Perhaps a larger, more positive slope translates into better memory encoding.

The following study tests the validity of these hypotheses for music. How do listeners derive a single remembered intensity from moment-to-moment intensities? Do any or all of the effects just discussed hold for experiencing music?

Method

PARTICIPANTS

Participants (N = 20) were college students at the University of Pennsylvania (13 female, 7 male, mean age = 21 years) who varied in musical experience (mean years of formal training = 5.53, range = 0–15 years). Participants were each paid $10.00/hr for participating.

PROCEDURE

On arrival, a single participant was seated in a comfortable chair in a well-lit and sound-attenuated room. One of the experimenters informed the participant that the study was concerned with “emotional responses to music.” The participant completed a self-report questionnaire regarding demographic information and musical experience and was then told that the experiment would entail listening to several musical selections ranging in style from classical to popular and in length from about 40 s to 3 min. The whole experiment lasted about 1 hr.

The experimenters then told the participant that the study was to explore subjective experiences of emotional intensity to be measured via a pressure-sensitive button on the right arm of the comfortable reclining chair in which the participant would sit. In this experiment, we chose to use a pressure-sensitive button rather than a dial or slider because the up-and-down motions needed to activate the button seem more analogous to increases and decreases in affective intensity than do the left-and-right motions used to manipulate a dial or slider (Clynes, 1977, 1980). Greater felt intensity (which often includes tensing of the forearms and fingers) is akin to pushing harder.

Using selections from the Overture to Mozart’s *The Abduction from Seraglio* and Schubert’s *String Quartet in A Minor,* D. 804 (Op. 29), the experimenters trained the participant to trace moment-to-moment experience with the pressure-sensitive button. The participant monitored a readout on a dial that tracked button activity to gain an understanding of the extremes and nuances of the scale. None had problems with the button, and all found the exercise quite natural.

After the brief training session, the participant heard the real stimuli but was instructed not to push the button during the first hearing of each selection but to wait for the second hearing. This allowed participants to become somewhat familiar with the music. After the second hearing of each selection, the music was stopped and the participant was instructed to rate the remembered intensity by pressing the button at the appropriate level for a few seconds. Further, the participant filled out a questionnaire regarding the selection just heard. Each participant rated how familiar the selection was on a scale from 1 (not familiar at all) to 7 (extremely familiar) as well as how much the participant liked each selection on a scale from 1 (hated it) to 7 (loved it).

STIMULI

Participants listened to 14 selections each played twice consecutively with the exceptions of Mozart’s *Eine Kleine Nachtmusik* and Queen’s “We Are the Champions,” which were played three times in order to see if participants’ button activity remains constant from hearing to hearing of the same piece. The order, performances, and specific durations of the selections are listed in Table 1. The 14 included two versions of Purcell's "When I Am Laid in Earth." One, the long version, consisted of two iterations of the short version. All selections were played from a CD through stereo speakers placed in front of the chair. Participants also brought one favorite selection with them to the lab on CD. This could be of any style or length.

APPARATUS AND DATA ANALYSIS

Participants expressed affective intensity by pressing a pressure-sensitive button. The button was attached to a lever that deflected a strain gage. The strain gage produced a change in resistance directly proportional to the change in force applied to the lever. This change in resistance was converted to a change in voltage, which was displayed by a dial readout. To make the button, and consequently the readout, respond more accurately to human touch, the dial display derived exponentially from button pressure:

$$\text{Meter Deflection} \sim (F \div 10)^{0.6} \qquad (1)$$

where F is force applied to the button. The readout ranged from 0 (no pressure) to 100 (maximum pressure). The output from the meter was amplified by a direct coupled bioamplifier (Colbourn, V75-03). The output of the amplifier was recorded by WINDAQ, a software package designed by Colbourn Instruments to record physiological data. We recorded 10 data points per second and then converted the data into Microsoft Excel files for analysis.

TABLE 1
Order of Selections in the Experiment

Composer: Piece	Performers/CD#	Time
Mozart: *Eine Kleine Nachtmusik,* I	Bruno Weil, Tafelmusik Sony Classical 46695	0:00–0:43
Purcell: *Dido and Aeneas,* "When I Am Laid in Earth"	Trevor Pinnock, The English Concert Deutshce Grammophon 427624-2	1:21–2:24
Chopin: Nocturne, Op. 9, No. 3	Artur Rubinstein RCA 7863-5613-2	0:00–0:45
Brahms: Symphony No. 1, I	Herbert Karajan, The Berlin Philharmonic Deutsche Grammophon 135084	5:18–5:50
James Brown: "I Feel Good"	James Brown PolyGram 101342	0:00–0:41
Brahms: Cello Sonata in E Minor, I	Yo-Yo Ma and Emanuel Ax RCDI-7022	0:00–0:23
Holst: *The Planets,* "Jupiter"	Herbert Karajan, The Berlin Philharmonic Deutsche Grammophon 400028-2	2:58–3:57
Queen: "We Are The Champions"	Queen UNI/Hollywood 1650209	0:00–1:12
Beethoven: Symphony No. 5 in C Minor, IV	Roger Norrington, The London Classical Players, EMI 7496562	0:00–0:36
Mozart: *Requiem,* "Lacrymosa"	Christopher Hogwood, The Academy of Ancient Music, Decca 411712-2	0:00–0:42
Borodin: String Quartet No. 2, iii	Borodin String Quartet EMI 7477952	0:00–1:16
Wagner: Prelude to *Tristan and Isolde*	Sir Colin Davis, London Symphony Orchestra, Philips 412655-2	2:00–2:31
Purcell: *Dido and Aeneas,* "When I Am Laid in Earth"	Trevor Pinnock, The English Concert Deutsche Grammophon 427624-2	1:21–1:52
Participant's choice		

Results

Two initial important results are the relationships between remembered intensity and each of aesthetic preference and familiarity. We computed two Pearson correlations for each participant. One was based on the 13 pairs (one for each selection, not including the short version of the Purcell example) of remembered intensity and aesthetic preference ratings and the other was based on the 13 pairs of remembered intensity and familiarity ratings (Table 2). For 18 of 20 participants, the correlations between remembered intensity and liking were positive, including 14 that were significantly above zero ($p < .01$). The average of the correlations was also significantly positive ($M = .66$, $SD = .31$), $t(19) = 9.47$, $p < .001$. That is, the more intense memories of a piece of music the listener has, the more that listener likes the piece. Table 2 also shows Pearson correlations between remembered intensity and familiarity. For 18 of the 20 participants, these correlations were positive, but only 5 were significantly so ($p < .01$). The average of these correlations was significantly positive ($M = .42$, $SD = .28$), $t(19) = 6.62$, $p < .001$. Although not as power-

TABLE 2

Pearson Correlations Between Remembered Emotional Intensity and Both Aesthetic Preference (Liking) and Familiarity for 20 Participants Across 13 Selections

	Correlation With Remembered Intensity[a]	
Participant	**Liking**	**Familiarity**
1	.93*	.73*
2	.85*	.84*
3	.89*	.68*
4	.79*	.58
5	.53	.49
6	.88*	–.10
7	.79*	.58
8	.00	.23
9	.78*	.14
10	.11	.07
11	.91*	.73*
12	.80*	.81*
13	.79*	–.09
14	.75*	.43
15	.87*	.40
16	.56	.28
17	.76*	.17
18	.63	.60
19	.78*	.40
20	–.15	.41
Mean[b]	.66*	.42*

[a] $df = 11$. [b] Significance of means based on t-test across 20 participants, $p < .001$.

* Significant at $p < .01$.

ful a connection as with liking, remembered intensity does seem to depend partly on familiarity.

In order to understand how composers and performers might generate intense memories, we determined Pearson correlations between remembered intensity and various characteristics of on-line experience for each participant (Table 3). Duration is the length of a musical selection. The average is the mean of participants' button activity during a selection. The sum is the combined total of all button activity for a given selection. The onset is the average of the first half-second of button activity for a given piece. Conversely, the offset is the average of the last half-second of button activity. The minimum is the lowest value of a participant's button activity during a selection. The peak is the maximum of button activity for a given piece. The last characteristic for which the correlation with remembered intensity is listed is the sum of the peak and the offset.

These data demonstrate duration neglect. Notice that remembered intensity is better predicted by the average of moment-to-moment affects (mean r = .80) than the sum of moment-to-moment affects (mean r = .55) for 19 of the 20 participants. A two-tailed dependent t-test on the differences indicated that this difference was significant (t = 6.02, p < .0001, df

TABLE 3

Pearson Correlations Between Remembered Emotional Intensity and Various Characteristics of On-line Experience

	Correlation[a]							
Participant	**Duration**	**Average**	**Sum**	**Onset**	**Offset**	**Minimum**	**Peak**	**Peak + Offset**
1	.23	_.79*_	.44	.17	**.50**	.13	**.74***	.74*
2	.19	**.85***	.44	.14	**.65***	.29	_.90*_	.83*
3	–.29	_.87*_	.42	.53	**.65***	.62	**.83***	.81*
4	–.06	**.84***	.39	.51	**.70***	.53	**.91***	_.93*_
5	.29	**.90***	.71*	.48	**.60**	.43	_.93*_	.78*
6	.41	_.75*_	.52	–.60	**.65***	–.43	**.69***	.71*
7	.28	**.72***	.68*	.14	**.48**	–.04	_.84*_	.81*
8	–.12	_.68*_	.10	.00	**.16**	–.31	**.54**	.51
9	–.11	**.82***	.36	.05	**.55**	.21	_.88*_	.75*
10	.25	**.69***	.55	.57	**.67***	.51	**.87***	_.89*_
11	–.11	**.72***	.65*	.51	**.70***	.53	**.83***	_.93*_
12	.19	.79*	**.80***	.62	_.93*_	.48	**.91***	.90*
13	–.19	**.85***	.45	**.70***	.62	.37	_.86*_	.85*
14	.32	_.84*_	.61	–.11	**.17**	.00	**.81***	.59
15	–.07	**.85***	.82*	.56	_.94*_	.69*	**.76***	.91*
16	.04	**.81***	.61	.55	_.92*_	.49	**.78***	.91*
17	–.02	**.82***	.28	–.32	_.94*_	–.45	**.72***	.81*
18	–.14	**.73***	.59	.39	**.73***	.55	_.88*_	.82*
19	.39	**.73***	.65*	.06	**.70***	–.19	_.75*_	.71*
20	.07	**.84***	.83*	.39	_.93*_	.41	**.83***	.84*
Mean[b]	.08	**.80***	.55	.27	**.67***	.24	_.82*_	.81*

NOTE—Bold indicates which of a pair of correlations (average vs. sum, onset vs. offset, minimum vs. peak) is higher. Italics indicate which correlation is highest for each participant. An asterisk (*) indicates significance at p < .01.

[a] df = 11. [b] Significance for mean based on t-test across the 20 participants, p < .01.

= 19). Because the sum depends on duration—all else being equal, more duration implies a larger sum—in contrast to average, which does not depend on duration, duration of an example seems to matter very little in the determination of remembered experience. Also, duration of a musical example does not correlate with remembered intensity. No participant showed a significantly positive correlation between duration and remembered intensity ($p < .01$).

Duration neglect also emerges in a comparison of participants' responses to two versions of "When I Am Laid in Earth" from *Dido and Aeneas*. A two-tailed *t*-test demonstrated that participants retrospectively rated the long version statistically the same as the short version ($t = 0.018$, $p = .96$, $df = 19$). That is, the extra duration of the longer version did not add to participants' memories of intensity.

End significance and peak significance clearly emerge from the data (Table 3). The offset, mean $r(20) = .67$, proved to be a better predictor of remembered intensity than did the onset, mean $r(20) = .27$, for 19 of 20 participants. A two-tailed *t*-test indicated that this result was significant ($t = -5.14$, $p < .0001$, $df = 19$). All 20 participants demonstrated a greater reliance on the peak, mean $r(20) = .82$, than on the minimum, mean $r(20) = .24$. This result also was statistically significant ($t = -8.32$, $p < .00001$, $df = 19$).

These data do not support the peak-end rule. Peak plus offset was the best predictor of remembered intensity for only three participants as compared with five for average, five for offset, and seven for peak. The *t*-tests showed that peak plus offset was not significantly different from peak alone ($t = 0.52$, $p = .61$, $df = 19$) or average ($t = -0.31$, p = .76, $df = 19$), although it was more predictive than offset ($t = 4.23$, $p = .0004$, $df = 19$). Average ($t = 2.78$, $p = .012$, $df = 19$) and peak ($t = -3.19$, $p = .005$, $df = 19$) were also more predictive than offset, but there was no difference between average and peak ($t = -0.94$, $p = .36$, $df = 19$).

Further analysis of the data revealed that peak significance and end significance are examples of more general effects. So that they can later serve to test the effectiveness of a model of how remembered affect derives from momentary affect, 10 participants (1–10) are omitted from the following statistical analysis of the recency, intensity, and slope effects. We will use half of the participants to empirically derive a theory of remembered affect and then test that theory against the remaining 10 participants.

End significance results from a *recency effect*. Recency is a well-known property of memory. All else being equal, greater amounts of time between initial learning of information and attempts to recall that information lead to less accurate recall. Details of the recency effect emerge from Pearson correlations between remembered intensity and values of on-line intensity at various times before the end of each selection. For example, we can calculate the correlation for each participant between the 13 remembered intensities of the 13 musical selections (not including the second version of the Purcell excerpt and using the second playings of *Eine Kleine Nacht Musik* and "We Are the Champions") and the 13 on-line values 0.1 s before the end. We can then do the same between remembered intensities and on-line values 0.2 s before the end, 0.3 s before the end, and so on. This provides a measure of how elapsed time influences remembered affect for an individual participant. Figure 1 shows a graph of these calculations for one participant's data, demonstrating that this participant's remembered intensities derive from more recent events (to the right of the chart) as opposed to more remote events (to the left of the chart). This figure also provides the same measure averaged across all participants (Figure 1). More recent on-line events (to the right) correlate with remembered experience more strongly than do less recent events (to the left). A logarithmic fit to this curve is very good, r^2 (209) = .91. Thus, at least for the 41-s window considered here, on-line experience fades logarithmically in memory. The 41-s span is the duration of the shortest selection. The more time that has elapsed since a moment occurred, the less influence that moment has on affective memory.

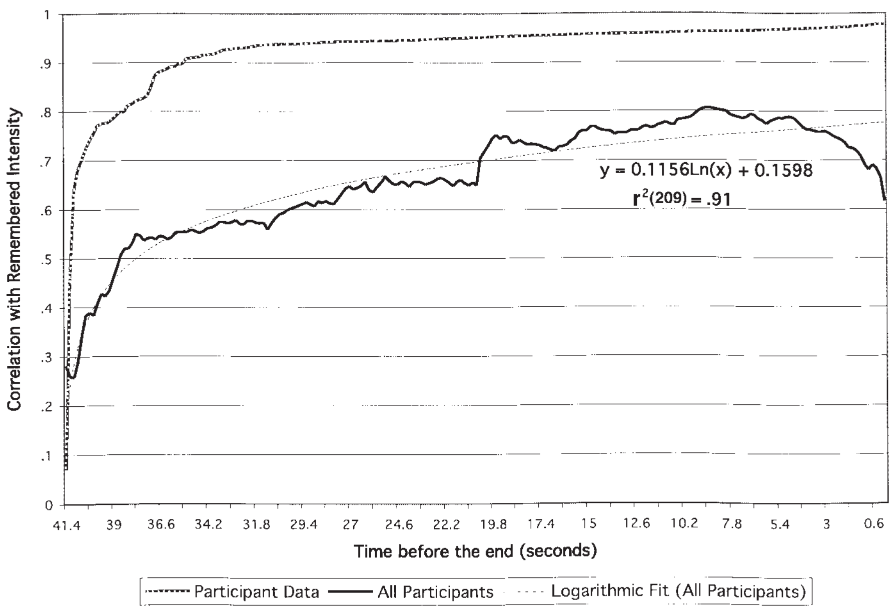

Fig. 1. Graph of correlations between remembered intensity and moment-to-moment intensities at various times before the end of a musical selection for a single participant and averaged across 10 participants. A fit to the curve indicates that the recency effect is logarithmic.

Peak significance is a symptom of an *intensity effect*. Details of the intensity effect emerge via correlations between remembered intensity and intensity-ranked values of on-line experience. For example, defining a "moment" as 0.1 s, we can calculate the correlations for an individual participant between the 13 remembered intensities and the most intense moments of on-line experience from each of the 13 selections (i.e., emotional peaks), between the remembered intensities and the second-most intense moments from each selection, and so forth until we reach the least intense moments (i.e., minimums). The peaks receive a ranking of 1, the second highest values receive a value of 2, and so on. This allows a comparison of the importance of on-line moments based on experienced emotional intensity. Figure 2 shows the intensity effect for one participant as well as the same averaged across all participants. As with the recency effect, the logarithmic fit is very good, r^2 (209) = .97. Listeners derive remembered experience primarily from the most intense moments of on-line experience (toward the right). The least intense moments (toward the left) contribute relatively little to affective memory.

Another effect that emerges from the data is a *slope effect*. A measure of the slope of a moment-to-moment curve is the difference between one moment and its immediate precursor (in this case, the moment 0.1 s

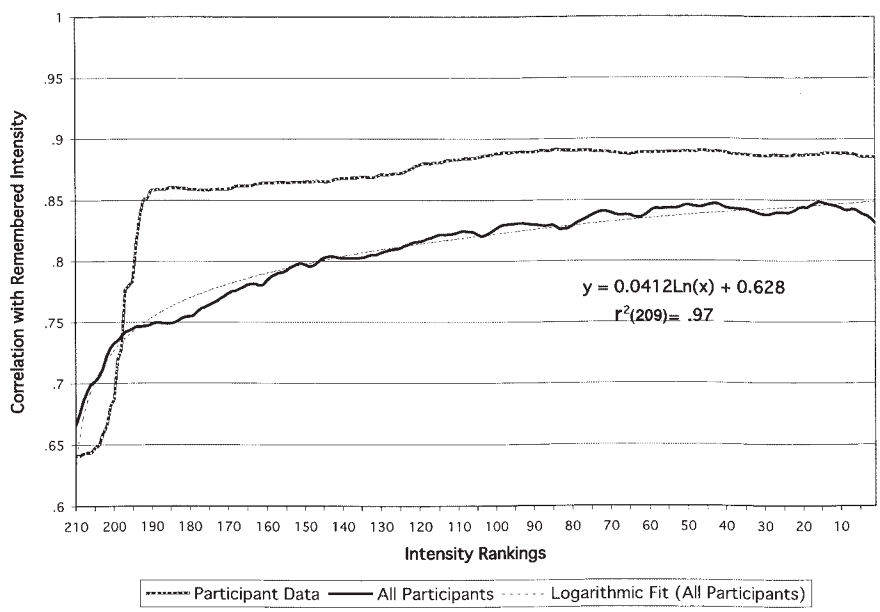

Fig. 2. Graph of correlations between remembered intensity and intensity-ranked values of moment-to-moment experience for a single participant and averaged across 10 participants. A fit to the curve indicates that the intensity effect is logarithmic.

beforehand). A large, positive difference between consecutive moments indicates that the slope is steep and thus that the second moment contrasts sharply and positively with its preceding context. Conversely, a small difference entails a shallow slope and that the second moment does not stand out in comparison to its previous temporal neighbor. We can calculate the correlations between remembered intensity and slope-ranked values. Figure 3 shows a graph of these for an individual participant and averaged across all participants. As slope increases (to the right) so does a moment's influence on remembered intensity. Moments that stand out of their immediate context fade from memory more slowly than other moments. The linear fit is very good, $r^2(208) = .92$.

What do the recency, intensity, and slope effects mean in terms of the affective memory process? When listeners attempt to evaluate a past musical episode, they consult their affective memories, which have distorted moment-to-moment experience in three consistent ways. The recency effect entails that each moment fades in memory at a logarithmic rate. Thus when listeners create a global evaluation of a phrase, piece, or concert, they have more difficulty accessing the details of moments from long ago. These moments have faded and play a very small role in calculations of remembered affect. Likewise, not so intense moments fade in memory

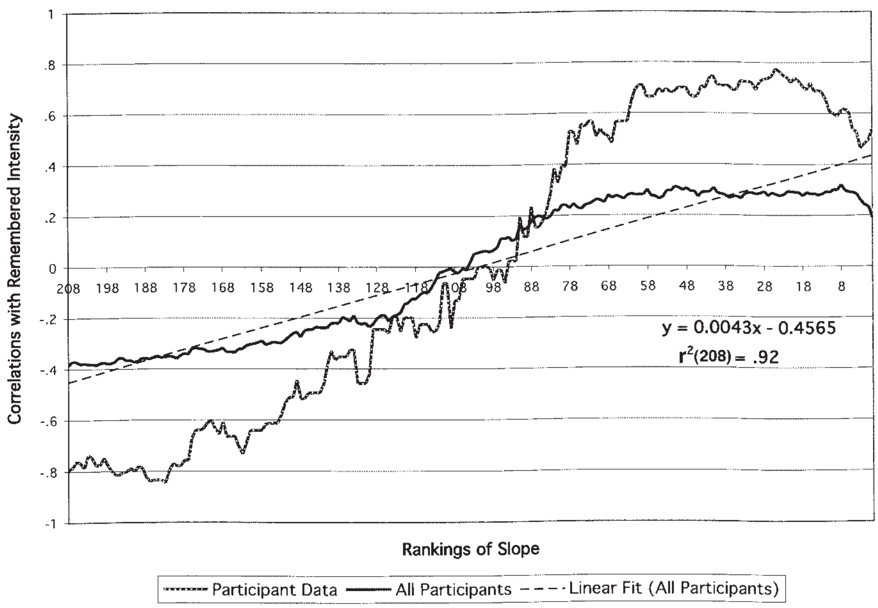

Fig. 3. Graph of correlations between remembered intensity and slope-ranked values of moment-to-moment experience for a single participant and averaged across 10 participants. A fit to the curve indicates that the intensity effect is linear.

very quickly. Thus these moments do not contribute significantly to retrospective evaluations. Very intense moments persist in memory (or do not fade as quickly) and hence greatly shape how listeners remember affect. The same is true for the slope effect. Moments that follow preceding moments of great intensity result in severely negative slopes and hence fade from memory rapidly and do not influence remembered intensity. Conversely, the impact of moments that follow moments of lesser intensity is great because these moments do not fade in memory.

It is possible to derive a formula that represents how listeners calculate remembered intensity. Each momentary intensity contributes to remembered intensity but not equally so. In essence, the affective information of each moment fades in memory to an extent that depends on how far from the end the moment occurred, how intense the moment was, and how the moment compared to the immediately preceding moment. Thus we can represent remembered intensity (RI) as a weighted sum of momentary intensities (MI), where each momentary intensity is adjusted by three coefficients: a recency coefficient (r), an intensity coefficient (i), and a slope coefficient (s). In mathematical symbols, the formula is:

$$\mathrm{RI} = \sum(\mathrm{MI}_n \times r_n \times i_n \times s_n), \tag{2}$$

where RI is the remembered intensity, MI_n is the momentary intensity at time t_n, r_n is the recency coefficient at time t_n, i_n is the intensity coefficient at time t_n, s_n is the slope coefficient at time t_n, and the sum is taken from $n = 1$ to $n =$ tend. This formula includes an implicit influence of duration on remembered intensity. Because it sums all momentary intensities, remembered affect will be greater for a longer musical episode. As duration increases significantly, however, its influence wanes because the recency coefficient ensures that moments long ago have little, if any, influence on remembered intensity.

The recency coefficient depends on when a moment occurs. Further, it is logarithmic with respect to the time (t_n) that a moment occurs following the empirical relation we described earlier:

$$r_n \sim \ln(t_n), \tag{3}$$

where r_n is the recency coefficient at time t_n. The largest coefficient will thus occur at the last moment when $t_n = t_{\mathrm{end}}$.

The intensity coefficient exaggerates the influence of highly intense moments in a logarithmic fashion. That is,

$$i_n \sim \ln(\mathrm{MI}_n) \tag{4}$$

where i_n is the intensity coefficient at time t_n and MI_n is the momentary intensity at time t_n. The most intense moment (i.e., the peak) produces the highest coefficient.

The slope coefficient derives from the intensity difference between a moment and the immediately preceding moment:

$$s_n \sim (\mathrm{MI}_n - \mathrm{MI}_{n-1}), \tag{5}$$

where s_n is the slope coefficient at time tn, MIn is the momentary intensity at time t_n, and MI_{n-1} is the momentary intensity at time t_{n-1}. As the slope increases, so does the slope coefficient, s_n. Thus the largest positive slope in a musical episode will result in the largest slope coefficient.

Combining equations 2 through 5 yields the formula for remembered intensity:

$$\mathrm{RI} \sim \sum [\mathrm{MI}_n \times \ln(t_n) \times \ln(\mathrm{MI}_n) \times (\mathrm{MI}_n - \mathrm{MI}_{n-1})] \tag{6}$$

This formula not only offers predictions of remembered intensity based on a series of momentary intensities, but it also represents the process of memory integration.

To appreciate the various components of this formula, let us consider graphically how each of the effects—recency, intensity, and slope—distorts moment-to-moment experience. Figure 4 shows one random participant's moment-to-moment intensities for the first eight bars of the "Lacrymosa" from Mozart's *Requiem* and a theoretical memory distortion of this on-line experience via the recency effect. The graph of the recency effect results from adjusting each point in the moment-to-moment

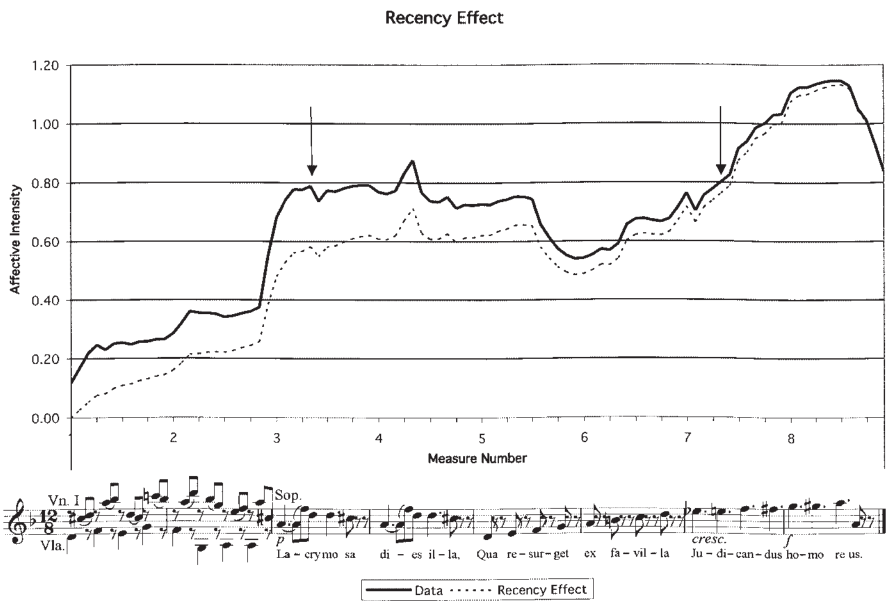

Fig. 4. How memory distorts one random participant's moment-to-moment experience via a recency effect for Mozart, *Requiem*, "Lacrymosa" (Larghetto), measures 1–8.

data using the recency formula (Equation 3). Notice that the recency effect does not change the basic shape of moment-to-moment experience. In fact, the correlation between these two curves is $r(209) = .98$. Despite overriding similarities, the recency effect does distort momentary experience in significant ways. For example, two moments that feel nearly identical as the piece is heard do not have equal effects on memory (see arrows in Figure 4).

Figure 5 shows how the intensity effect distorts the same participant's moment-to-moment experience of this phrase from Mozart's *Requiem*. As with the recency effect, the intensity effect does not change the general shape of the moment-to-moment curve. The correlation between these curves is $r(209) = .99$. However, the intensity effect slightly exaggerates the contour of the curve, amplifying the differences between valleys and peaks and creating a somewhat more jagged representation.

In contrast, the slope effect more dramatically alters moment-to-moment experience. Figure 6 captures how memory misrepresents on-line experience via the slope effect. Unlike the recency and intensity effects, the slope effect significantly changes the shape of the moment-to-moment curve. It greatly dampens the memory of the end, whereas it does relatively little to lessen the effects of the moment when the voices enter in bar 3. The correlation between these curves is still high at $r(209) = .60$ but much lower than that for either the recency or the intensity effect.

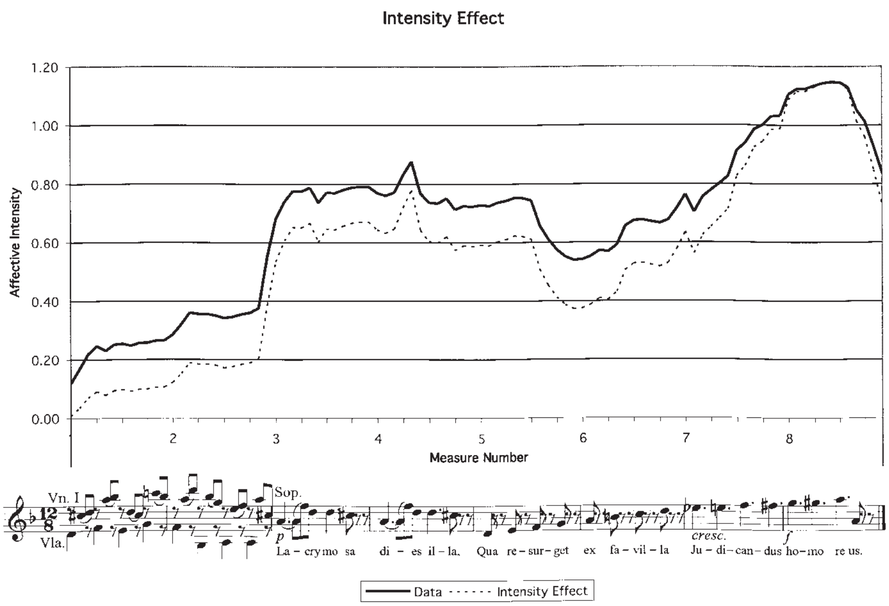

Fig. 5. How memory distorts one random participant's moment-to-moment experience via an intensity effect for Mozart, *Requiem*, "Lacrymosa" (Larghetto), measures 1–8.

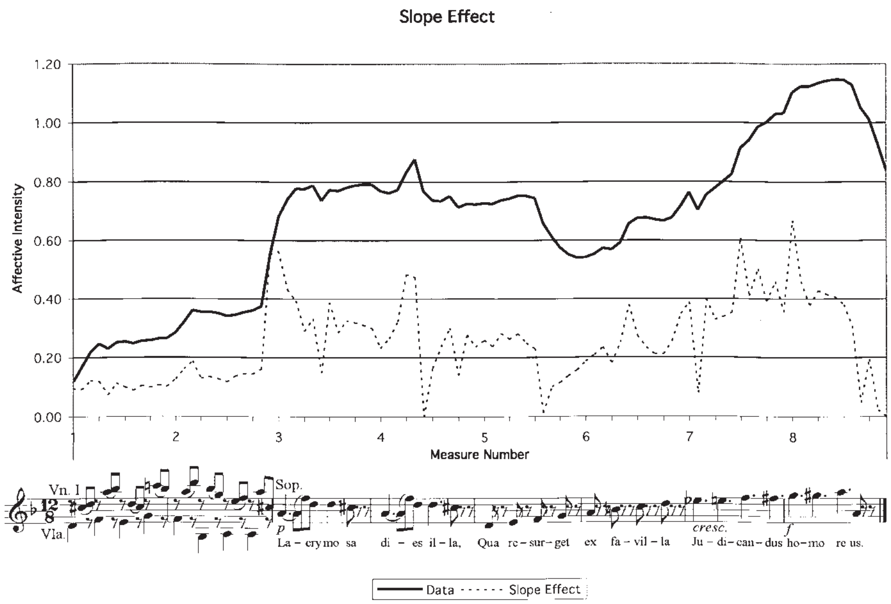

Fig. 6. How memory distorts one random participant's moment-to-moment experience via a slope effect for Mozart, *Requiem,* "Lacrymosa" (Larghetto), measures 1–8.

Figure 7 represents both temporal frames of affect for this phrase from Mozart's *Requiem*. Remembered affect derives from the combined influence of the recency, intensity, and slope effects on moment-to-moment affect. The combination of these effects produces a curve that correlates highly with the original, $r(209) = .78$, but that shows that memory distorts every moment of on-line experience. The superimposition of the two curves allows readers to clearly distinguish between temporal frames and to discover which moments develop into important remembered events and which fade into obscurity.[1]

In order to test whether the formula that calculates remembered affect from moment-to-moment affect is a better predictor than any of the on-line characteristics considered in Table 3, we can apply the formula to the 10 participants' data not included in the derivation of the formula. Table 4 shows the correlations between the formula's predictions and each of these 10 participant's remembered intensities. The formula is the best predictor for 8 of the 10 participants. Two-tailed *t*-tests indicate that the formula is significantly better than offset ($t = -7.47$, $p < .0001$, $df = 9$), aver-

1. In order to bring this simultaneous presentation of temporal frames into the realm of more traditional music analysis, one could translate these representations into music notation. This idea derives from Narmour's (1984) decision to represent hierarchical levels (or, more appropriately, ranks) by sizes of noteheads. Similarly, one could represent more important affective events with bigger noteheads.

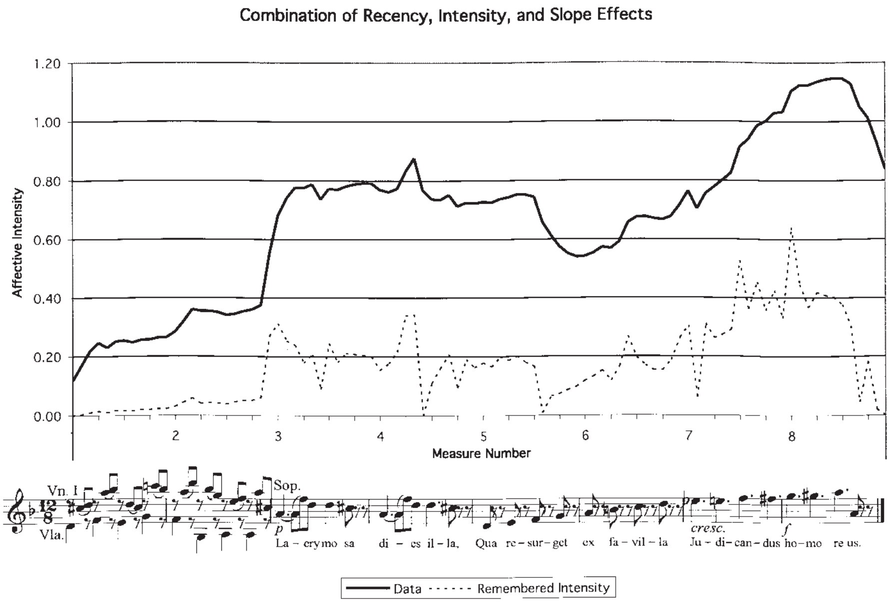

Fig. 7. How memory distorts one random participant's moment-to-moment experience via the combination of recency, intensity, and slope effects for Mozart, *Requiem*, "Lacrymosa" (Larghetto), measures 1–8.

age (t = –4.05, p = .003, df = 9), peak (t = –2.37, p = .01, df = 9), and peak plus offset (t = –3.65, p = .005, df = 9).

A further test of this formula's power is to compare its predictions with results of a multiple regression involving various on-line characteristics (Table 4). Because the formula is essentially an adjusted sum, we include

TABLE 4

Pearson Correlations Between Predictions of How Listeners Determine Postperformance Emotional Intensity and Data for 10 Participants

Participant	r (Prediction vs. Data)[a]	Multiple R
1	**.86***	.84
2	**.91***	.92
3	**.90***	.89
4	.90*	.94
5	.92*	.95
6	**.81***	.78
7	**.88***	.88
8	**.79***	.74
9	**.89***	.90
10	**.91***	.90
Mean[b]	**.87***	.87

NOTE—Multiple R's from a regression including sum, peak, and offset are presented for comparison. An asterisk (*) indicates significance at $p < .01$. Bold indicates whether this correlation is the highest for each participant compared with the variables considered in Table 3.

[a] df = 11. [b] Significance for mean based on t test across the 10 participants, $p < .01$.

the sum of moment-to-moment experience in the regression as well as the peak and offset because they are the most important individual moments of on-line experience. The results of this regression indicate that the combination of sum, peak, and offset is as good as the model just derived at predicting remembered affect. Although not more powerful than sum, peak, and offset, the model we present is more theoretically satisfying. It seems unlikely that listeners would be able to keep an accurate running summation of a musical experience, allowing them to use the information to determine retrospective evaluations.

Discussion

The results of this experiment confirm the four hypotheses. Participants exhibited duration neglect. However, the current data do not support Ariely's (1998) argument: that duration neglect is markedly attenuated for heterogeneous stimuli such as classical and popular music as opposed to for homogeneous stimuli such as ice water. The peak value of momentary intensity and the end value both significantly influence listeners' retrospective judgments of music. Last, the moment-to-moment context also shapes remembered affect. A momentary intensity that is much greater than the previous momentary intensity greatly influences determinations of remembered intensity.

If remembered affect largely determines whether listeners pay to see a specific concert for a second time or to replay a favorite CD, then it behooves composers and performers to evoke high degrees of remembered affect rather than moment-to-moment affect. If composers and performers want audiences to return to their music, then they need to learn how to shape listeners' memories (and, clearly, successful composers and performers already understand this intuitively). The recency, intensity, and slope effects should thus tell us much about what successful composers and performers do to maximize remembered affect. How they construct and express phrases, movements, pieces, and entire concerts should demonstrate how these effects lead to more intense memories.

Although the experimental results speak only to a very limited time frame (around 40 s), it is possible, even likely, that these types of distortions of memory occur in larger durations as well. The success of a movement, piece, or entire concert may hinge on the same principles as phrases. Consider the third movement of Borodin's String Quartet No. 2. The first author always remembers this movement fondly and as a particularly intense 8 min of music. However, each time he hears the movement, he loses interest about two-thirds to three-quarters of the way through. In other words, a serious portion of the moment-to-moment experience consistently fails to draw his attention as the rest of the piece does. Yet he returns again and again to the movement because he remembers it as a wonderful experience.

To examine why this might be so, we begin with a brief description of the first author's moment-to-moment experience of this movement. We divide the movement into seven sections, coinciding with the rehearsal letters (Table 5). The section-by-section intensity ratings derive from his experience and are based on a scale of 1 to 10, where 1 is not intense at all and 10 is extremely intense. They reflect his highly affective responses to the opening cello theme (mm. 1–23) and to the "love duet" between cello and violin (mm. 111–132). They also reflect his lack of interest in the second love duet between the two violins (mm. 133–155). What if, instead of this second love duet, Borodin had composed something that evoked a high degree of affect? What if this section had elicited an 8 out of 10 rather than a 2? The remembered intensities for the first author's actual experience and the "what if" scenario are nearly identical (Table 5, bottom row). The increase in momentary affect does not add (and, in fact, subtracts) from remembered affect. The explanation for this resides in the slope effect. Although the original music evokes only a 2 out of 10, it creates a steep slope in comparison to the following section (= 8 – 2 = 6). The "what if" ratings take away the slope completely (= 8 – 8 = 0) and hence diminish the impact of the final section on memory. (The hypothetical ratings would produce less remembered intensity not just if mm. 133–155 rated as an 8 but if they rated anywhere between 3 and 8. With a 1, 9, or 10, the remembered intensity increases in comparison to the original.) A part of the success of this movement, then, is the lack of success of measures 133–155. Increases in momentary affect do not necessarily translate into increases in remembered affect.

Taking the recency, intensity, and slope effects to an even larger time frame, the rationale for arrangements of movements within a piece such as within a classical four-movement symphony might also depend on how

TABLE 5

The First Author's Intensity Ratings of Sections From the Third Movement of Borodin's String Quartet No.2, III (Andante)

Measures	Time*	Intensity Ratings	"What If" Intensity Ratings
1–23	0:00-1:17	8	8
24–47	1:17-2:29	7	7
48–66	2:29-3:09	4	4
67–110	3:09-4:44	6	6
111–132	4:44-5:56	9	9
133–155	5:56-7:00	**2**	**8**
156–180	7:00-8:32	8	8
Remembered intensity		22.53	22.43

* The times are based on a CD of the Borodin String Quartet, EMI, 1987.

memory distorts moment-to-moment experience, a speculation currently being tested at the University of Pennsylvania. One common plan for a Haydn symphony, for example, consists of relatively intense outer movements (fast tempos, loud dynamics, full orchestral textures) and relatively less arousing inner movements (slow tempos, quiet dynamics, thinner textures). A movement-by-movement intensity rating might be 9 out of 10 for the first movement, 3 for the second, 4 for the third, and 8 for the finale. Why did Haydn and many other composers use this arrangement? One possible answer is that memory's effects make this arrangement the most intense retrospectively. If we calculate the remembered intensity for every possible permutation of four movements with the ratings 3, 4, 8, and 9, we find that the four permutations that generate the most remembered affect are the ones that have the most intense movements (i.e., 8 and 9) as the outer movements (Table 6). One important component of this arrangement of movements is the finale. Because of the recency effect, the last movement contributes heavily to remembered affect. Thus the movement cycles that end with an 8 or a 9 produce greater amounts of remembered intensity. The slope effect is the other key component of this array of movements. The slope is large approaching both the first and last movements. The first movement follows nothing and hence generates a steep slope just as the last movement does by following one of the less intense movements.

The permutations that generate the least remembered affect have the most intense movements as inner movements. These take advantage of neither the recency effect by "ending with a bang" nor the slope effect by

TABLE 6

Theoretically Derived Remembered Intensities for Every Permutation of Four Movements Within a Symphony Given Ratings of 3, 4, 8, and 9 for the Individual Movements

Permutation	Remembered Intensity	Permutation	Remembered Intensity
3-4-8-9	12.34	**8-3-4-9**	**15.08**
3-4-9-8	12.04	8-3-9-4	14.09
3-8-4-9	13.93	**8-4-3-9**	**15.18**
3-8-9-4	*11.19*	8-4-9-3	13.61
3-9-4-8	13.61	8-9-3-4	12.33
3-9-8-4	*11.16*	8-9-4-3	11.75
4-3-8-9	12.88	**9-3-4-8**	**14.85**
4-3-9-8	12.65	9-3-8-4	14.07
4-8-3-9	14.58	**9-4-3-8**	**14.81**
4-8-9-3	*11.34*	9-4-8-3	13.52
4-9-3-8	14.22	9-8-3-4	12.30
4-9-8-3	*11.19*	9-8-4-3	11.78

NOTE—Bold indicates the permutations that produce the greatest amount of remembered emotional intensity. Italics indicate the permutations that produce the least amount of remembered emotional intensity.

beginning with a steep slope. Further, these permutations dampen the impact on memory of one of the intense movements. The third movement in the 4-8-9-3 permutation, for example, loses much of its influence on memory because it follows a movement of high intensity and hence does not generate a large slope.

Conclusions

Remembered affect plays an enormous role in the determination of future musical behavior. This study demonstrates that remembered affect is not “to a good approximation just the sum of the values of the individual experiences of parts.” Rather, listeners’ memories distort momentary affect in specific ways that tell us much about how successful composers and performers ply their crafts. Although some of the lessons learned are rather obvious, for example, that because of the recency effect many successful pieces end with a bang, others are not so intuitive. Most notably, the slope effect suggests that a phrase, movement, piece, or entire concert needs affective valleys just as it needs affective peaks. Without low points to provide contrast, high points would not pack the remembered punch that they otherwise would.

In order to maximize listeners’ remembered intensity, composers and performers must avoid being greedy. Every moment need not rivet the audience. Rather, listeners require periods of respite that accentuate affective highs in their memories and provide moments of cognitive relaxation. Often, young musicians struggle to create experiences that hold listeners’ attention throughout. However, it seems that this is not such a wise endeavor. The maturation process for a musician in part involves a growing understanding of how weak musical moments can enhance memories of an entire piece and of how sacrificing a bit of the present can intensify listeners’ memories of the past.[2]

References

Ariely, D. (1998). Combining experiences over time: The effects of duration, intensity changes and on-line measurements on retrospective pain evaluations. *Journal of Behavioral Decision Making, 11,* 19–45.

Baumgartner, H., Sujan, M., & Padgett, D. (1997). Patterns of affective reactions to advertisements: The integration of moment-to-moment responses into overall judgments. *Journal of Marketing Research, 34,* 219–232.

Clynes, M. (1977). *Sentics: The touch of emotions.* Garden City, NY: Anchor/Doubleday.

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Clynes, M. (1980). The communication of emotion: Theory of sentics. In R. Plutchik & H. Kellerman (Eds.), *Emotion: Theory, research and experience* (pp. 171–216). New York: Academic Press.

Dutta, S., & Kanungo, R. N. (1975). *Affect and memory: A reformulation.* Oxford: Pergamon Press.

Fredrickson, B. L., & Kahneman, D. (1993). Duration neglect in retrospective evaluations of affective episodes. *Journal of Personality and Social Psychology, 65,* 45–55.

Fredrickson, W. (1995). A comparison of perceived musical tension and aesthetic response. *Psychology of Music, 23,* 81–87.

Gold, P. (1987). Sweet memories. *American Scientist, 75,* 151–155.

Gregory, D. (1989). Using computers to measure continuous music responses. *Psychomusicology, 8,* 127–134.

Gundlach, R. H. (1935). Factors determining the characterization of musical phrases. *American Journal of Psychology, 47,* 624–644.

Gurney, E. (1880). *The power of sound.* London: Smith, Elder.

Hall, J., Gonder-Frederick, L., Chewning, W., Silveira, J., & Gold, P. (1989). Glucose enhancement of memory in young and aged humans. *Neuropsychologia, 27,* 1129–1138.

Hasty, C. F. (1997). *Meter as rhythm.* New York: Oxford University Press.

Heuer, F., & Reisberg, D. (1990). Vivid memories of emotional events: The accuracy of remembered minutiae. *Memory and Cognition, 18,* 496–506.

Hsee, C. K., & Abelson, R. P. (1991). Velocity relation: Satisfaction as a function of the first derivative of outcome over time. *Journal of Personality and Social Psychology, 60,* 341–347.

Imberty, M. (1979). *Entendre la musique.* Paris: Dunod.

Jackendoff, R. (1992). Musical processing and musical affect. In M. R. Jones & S. Holleran (Eds.), *Cognitive bases of musical communication* (pp. 51–68). Washington, DC: American Psychological Association.

Kahneman, D., Fredrickson, B. L., Schreiber, C. A., & Redelmeier, D. A. (1993). When more pain is preferred to less: adding a better end. *Psychological Science, 4,* 401–405.

Kahneman, D., Wakker, P. P., & Sarin, R. (1997). Back to Bentham? Explorations of experienced utility. *The Quarterly Journal of Economics, 112,* 375–405.

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

Lerdahl, F., & Jackendoff, R. (1983). *A generative theory of tonal music.* Cambridge, MA: The MIT Press.

Levinson, J. (1997). *Music in the moment.* Ithaca, NY: Cornell University Press.

Loewenstein, G. F., & Prelec, D. (1993). Preferences for sequences of outcomes. *Psychological Review, 100,* 91–108.

Madsen, C. K. (1990). Measuring musical response. *Music Educators Journal, 77*(3), 26–28.

Madsen, C. K. (1996, August). *Empirical investigation of the "aesthetic response" to music: Musicians and nonmusicians.* Paper presented at The Fourth International Conference on Music Perception and Cognition, Montreal, Canada.

Madsen, C. K., Byrnes, S. R., Capperella-Sheldon, D. A., & Brittin, R. V. (1993). Aesthetic response to music: Musicians versus nonmusicians. *Journal of Music Therapy, 30,* 174–191.

Madsen, C. K., Capperella-Sheldon, D., & Johnson, C. (1991). Use of continuous response digital interface (CRDI) in evaluating music responses of special populations. *Journal of the International Association of Music for the Handicapped, 6*(2), 3–15.

Madsen, C. K., & Fredrickson., W. E. (1993). The experience of musical tension: A replication of Nielsen's research using the continuous response digital interface. *Journal of Music Therapy 30,* 46–63.

Manning, C., J. Hall, J., & Gold, P. (1990). Glucose effects on memory and other neuropsychological tests in elderly humans. *Psychological Science, 1,* 307–311.

Meyer, L. B. (1956). *Emotion and meaning in music.* Chicago: The University of Chicago Press.

Meyer, L. B. (1973). *Explaining music: Essays and explorations.* Chicago: The University of Chicago Press.

Narmour, E. (1984). Some major theoretical problems concerning the concept of hierarchy in the analysis of tonal music. *Music Perception, 1,* 129–199.

Narmour, E. (1990). The analysis and cognition of basic melodic structures. Chicago: The University of Chicago Press.

Narmour, E. (1991). The top-down and bottom-up systems of musical implication: Building on Meyer's theory of emotional syntax. *Music Perception, 9,* 1–26.

Narmour, E. (1992). *The analysis and cognition of melodic complexity.* Chicago: The University of Chicago Press.

Narmour, E. (1996). Analyzing form and measuring perceptual content in Mozart's Sonata K. 282: A new theory of parametric analogues. *Music Perception, 13,* 265–318.

Narmour, E. (1999). Hierarchical expectation and musical style. In D. Deutsch (Ed.), *The psychology of music* (2nd ed., pp. 441–472). San Diego: Academic Press.

Nielsen, F. V. (1983). *Oplevelse af musikalsk spaending [The experience of musical tension].* Copenhagen: Akademisk Forlag.

Redelmeier, D. A., & Kahneman, D. (1996). Patients' memories of painful medical treatments: Real-time and retrospective evaluations of two minimally invasive procedures. *Pain, 116,* 3–8.

Rigg, M. (1937). An experiment to determine how accurately college students can interpret the intended meanings of musical compositions. *Journal of Experimental Psychology, 21,* 223–239.

Rode, E., Rozin, P., & Durlach, P. (2004). *Experienced and remembered pleasure for meals: Duration neglect but minimal peak-end effects.* Manuscript submitted for publication.

Rozin, A. (2000). *The intensity of musical affect: A model of experience and memory.* Unpublished doctoral dissertation, University of Pennsylvania.

Sloboda, J., & Lehmann, A. (2001). Tracking perceived emotionality in a prelude. *Music Perception, 19,* 87–120.

Waterman, M. (1996). Emotional responses to music: Implicit and explicit effects in listeners and performers. *Psychology of Music, 24,* 53–67.

Watson, K. B. (1942). The nature and measurement of musical meanings. *Psychological Monographs, 54,* 1–54.

Wedin, L. (1972). A multidimensional study of perceptual-emotional qualities in music. *Scandinavian Journal of Psychology, 13,* 241–257.