

Some influences of accent structure on melody recognition

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Two experiments were carried out to investigate the roles of joint accent structure and familiarity in delayed recognition of relatively long tonal melodies. Melodic themes of target melodies were defined by correlating contour-related pitch accents with temporal accents (accent coupling) during an initial familiarization phase. Later, subjects gave recognition responses to key-transposed versions of the target melodies as well as to decoys with *same* and *different* contour accent patterns. In Experiment 1, all to-be-recognized melodies occurred both in an original rhythm, which preserved accent coupling, and in a new rhythm, which did not. Listeners were best at distinguishing targets from *different* decoys, especially in the original rhythm. In Experiment 2, the familiarity of target tunes and the rhythmic similarity in recognition were varied. *Similar* rhythms preserved accent coupling, whereas *dissimilar* rhythms did not. Listeners were most adept in distinguishing familiar targets from *different* decoys (Experiment 2A), particularly when they appeared in novel but similar rhythms. However, in *similar* rhythm conditions, listeners also frequently mistook *same* decoys for targets. With less familiar targets (Experiment 2B), these effects were attenuated, and performance showed general effects of pitch contour.

In this article, we will examine the average listener's ability to recognize melodic themes and variations in music as a function of rhythmic context. The issue of memory for melody is not unrelated to memory for other kinds of material, such as ballads, poems, and TV jingles (see, e.g., Wallace & Rubin, in press). All have some claim to establishing in listeners a dynamic structure that influences later recognition. In the present research, we have explored certain relationships between the form of an original event and that of its dynamic reinstatement.

In musical compositions, composers commonly announce a melodic theme and follow it with several variations, thereby evoking different levels of recognition in listeners. Indeed, whereas a psychologist may wonder what degrades melodic recognizability, composers seem to know this intuitively and capitalize on it to evoke different degrees of thematic clarity. Their techniques yield variations that are based on rearrangements of both melodic (tonal) and rhythmic (temporal) elements of the original event. In the present research, we rely on simple definitions of melodic and rhythmic parameters to explore their impact on melody recognition. Our general goal is to in-

vestigate ways in which different combinations of melodic and rhythmic accent patterns evoke a recognition response of some earlier theme.

Background

In tonal music, a melody is a particular serial arrangement of pitch intervals that also establishes a sense of key. *Pitch intervals*, measured in logarithmic units (semitones, ST), are the pitch distances between successive frequencies.¹ Variations of a melody often involve systematic changes of these intervals or of the pitches themselves. For instance, a uniform change of all pitches to higher or lower frequencies that preserves both a melody's serial order and its pitch interval properties is a variation in which the theme is easily recognized (see, e.g., Burbidge & Jones, 1982; Dowling & Harwood, 1986). Even some serial rearrangements of pitches that preserve relatively few adjacent pitch intervals still move listeners to "hear" the original theme, presumably because these rearrangements capture attention-getting aspects of the original melody. One such variation that will be of interest is that which preserves a melody's contour, namely its "ups" and "downs" in pitch (Dowling, 1978; Dowling & Fujitani, 1971; Dyson & Watkins, 1984; Edworthy, 1985; Jones, Summerell, & Marshburn, 1987; Watkins, 1985). At least with short unfamiliar sequences, invariances in pitch contour have a pronounced influence on melody recognition, particularly after brief retention intervals (Bartlett & Dowling, 1980; Dowling & Bartlett, 1981; Dowling & Harwood, 1986). One reason why pitch contour has such powerful effects may be that contour itself offers salient accents that are based on directional pitch changes (Boltz & Jones, 1986; Thomassen, 1982).

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The fact that any melody is a temporal arrangement of pitches underscores that its structure depends fundamentally on relationships of pitches *in time*. *Relative timing* refers to the time of one event, taken with reference to the time of another, and it is variously expressed (e.g., as ordinal, interval, or ratio time relations) (Jones, 1976). Relative timing among different pitches is an integral part of a melody's structure, in which timed pitches can occupy adjacent or nonadjacent serial locations. The fact that a melody's pitch contour can be psychologically compelling attests to the import of time relations among *non-adjacent* events, because usually the pitches that mark contour changes are nonadjacent events.

This raises the possibility that people attend selectively in time to nonadjacent events (Jones, 1976). For instance, pitches at contour change points may attract more attention and ultimately form a more memorable, higher order melodic theme for listeners. If so, time relations among these pitches should govern "when" people attend, and hence "what" they remember (Jones & Boltz, 1989).

In the present analysis, it is assumed that pitch contour contributes to a psychologically salient accent pattern. At least some recent work on pitch accenting questions this assumption (Deliege, 1987). However, in this and in related work that casts doubt on the general salience of pitch relationships, relatively short and/or isochronous tunes have been employed (see, e.g., Monahan & Carterette, 1985). Since pitch accents are often associated with nonadjacent events, it is possible that their influence will be more evident in longer tunes. Relatively long, rhythmically patterned tonal melodies were the stimuli in the present delayed recognition task. We varied the extent to which a to-be-recognized tune preserved certain time relations among contour-related pitch accents of previously presented melodies. In recognition, these time relationships were preserved among all pitches of a melody, among only certain nonadjacent accented pitches, or among neither adjacent nor nonadjacent pitches. In an attempt to influence listeners' attention to these pitch accent points, we also varied the rhythm in which to-be-recognized melodies occurred, so that the pitch theme carried by nonadjacent notes was either selectively highlighted temporally or not.

The design is identical to that of Jones et al. (1987). In recognition, listeners attempted to differentiate previously presented targets from decoys with *same* and *different* contours. Each target melody and its associated decoys occurred either in an original rhythm (one associated with it in an earlier familiarization phase) or in a new rhythm. Using this procedure, Jones et al. found that listeners had difficulty recognizing targets in the new rhythm, and tended to mistake the decoys that shared the target's pitch contour for targets, especially when they appeared in the target's original rhythm. Although these findings are consistent with the idea that contour and rhythm jointly influence memory for melody, they do not specifically address how this happens. In the present research, different melodies and rhythms were used to pursue this issue.

A construct that guided selection of melodies and rhythms in the present research is *joint accent structure*, which Jones (1987) proposed guides dynamic attending to auditory events in many different tasks (see, e.g., Boltz & Jones, 1986; Jones, Boltz, & Kidd, 1982; Martin, 1972; Monahan & Carterette, 1985; Yeston, 1976). A joint accent structure is an accent/time hierarchy in which differentially weighted pitch and time accents are linked together by nested time relations (Jones, 1976). Relational properties of the joint accent structure determine, in part, expectancies about the pitch and time values of forthcoming events in a tune (Jones, 1976, 1981, 1982). Here we assume that: (1) pitch (e.g., melodic) and time (e.g., rhythmic) structures each contribute distinctive accents to this combined pattern, and co-occurring, namely *coupled*, accents receive more *accent weight*; (2) a melodic theme is specified primarily by time relationships among accented pitches of different weights; and (3) pitches that receive stronger accent weights reflect higher level properties of a joint accent structure, and because of their prominence in pitch or in time or both, they are more attention-getting and hence more likely to establish the theme.

If people rely on such accent structures to selectively attend to a higher order melodic line, we can ask, "What changes in joint accent structure degrade listeners' ability to recognize a target melody?" and, relatedly, "What changes in joint accent structure continue to support thematic clarity?"

The Experimental Rationale

To address such questions, the experimental rationale involved manipulations of two aspects of joint accent structure in order to assess their impact on theme recognition. These aspects involved: (1) time relations among certain pitch accents; and (2) temporal phasing of pitch and time accents (accent coupling). Manipulations of these properties are illustrated with examples of recognition tunes in Figure 1.

Time relations among pitches in various target and decoy melodies were varied across the central segments of various recognition tunes with special attention to pitches marking contour changes. Essentially, we tampered with pitch placements in the middle of each tune by systematically varying the signed interval time values that obtained between onsets of central pitches and ones in the surrounding context. Consider, for example, the target melody depicted in Figures 1a and 1d; its contour peaks are marked with key-related pitches denoted musically as G₅, G₄, A₄, C₄, F₄, and B₃. Such pitches are termed *contour-pitch accents*, and they can differ in prominence or weight.² The most prominent contour-pitch accent is G₅, which establishes its time relation to the opening tonic (C₄) by virtue of its placement at the seventh serial location. Both the accent weight and the relative time value (e.g., with respect to the opening tonic) of such a pitch enter into hierarchical properties of this tune's joint accent structure and thus contribute to its thematic character. Similarities and differences among targets and decoys in the present research play on this idea. Thus, compare this tar-

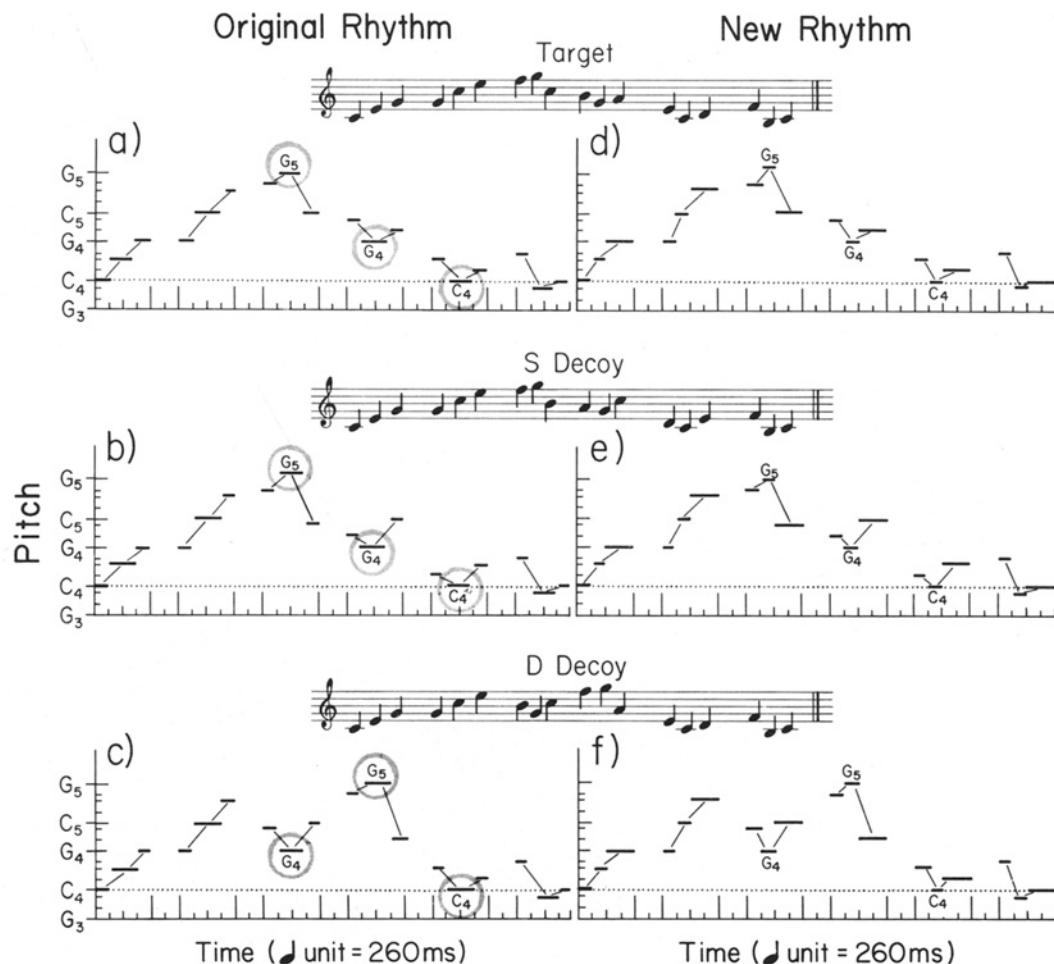


Figure 1. Target, *same* (S), and *different* (D) decoy melodies in both the original (a, b, c) and new rhythms (d, e, f). Circled notes are pitch-contour accents that are coupled with temporal accents (i.e., longer notes); these coupled accents occur in the original, but not in the new, rhythm (Experiment 1).

get to a decoy with the same pitch contour shown in Figures 1b and 1e. Although this decoy manifests numerous changes in the serial locations of pitches in its central portion, it nonetheless has the same contour as the target. In fact, most of the same contour-pitch accents occur at the same serial locations. This is most evident for the prominent contour-pitch accent, G₅, which has the same time interval relation with the opening tonic in both tunes. By contrast, a decoy with a pitch contour that is different from the target's is shown in Figures 1c and 1f. It has more changes in the serial loci of its central pitches because some contour-pitch accents have also been shifted. Thus, the global pitch peak, marked by G₅, is temporally shifted farther from the opening segment than it is in the other two tunes.³ In other respects, the two decoys share many features (see the Method section).

In sum, relatively long tonal melodies, which open and close with similar key-specific information (in this case C major) and which offer a higher order melodic line of contour-pitch accents, are systematically manipulated with respect to their relative time properties. The hypothe-

sis of interest maintains that if listeners rely on time relations among these sorts of pitch accents to selectively track this theme, then *same* decoys should be mistaken for targets more often than *different* decoys.

To pursue this further, rhythm was manipulated so that in some cases it highlighted nonadjacent events associated with the higher order melodic line, whereas in other cases it did not. Given a joint accent structure analysis, it is possible to devise rhythmic contexts that add prominence to contour-pitch accents by correlating them with temporal accents; this was done with target melodies in the first phase of the experiments reported here. Each of three rhythmic figures was tailored to a target melody such that its *time accents* (e.g., lengthened durations) tended to coincide with the melody's contour-pitch accents. The rhythms were three simple and predictable durational patterns, each combining long (L) and short (S) durations with the L tone durations taken as temporally accented ones. They differed from one another only with respect to placement of the temporal accent (L) within successive three-tone groups, each group being identically punc-

tuated by a pause (i.e., SSL pause SSL . . . , SLS pause SLS . . . , LSS pause LSS . . .). Thus, whenever a time accent coincides with a pitch accent, *accent coupling* results (Jones & Boltz, 1989). Coupled accents are assumed to have more attention-getting weight, particularly with untrained listeners (Monahan, Kendall, & Carterette, 1987). In familiarization, all target melodies had several coupled accents by virtue of the rhythm assigned to them.

In recognition, rhythm was explicitly manipulated so that all tunes appeared both in their original (or a *similar*) rhythm, and so preserved accent coupling, and in a new (or *dissimilar*) rhythm where accent coupling did not occur. Figures 1a, 1b, and 1c show accent coupling in targets, *same* decoys, and *different* decoys with the original rhythm (e.g., SLS); circled tones from the central segments of various melodies indicate weightier accents due to couplings with this rhythm. The same melodies appear in a new rhythm (SSL) in Figures 1d, 1e, and 1f. Note that temporal accents are phase-shifted relative to contour-pitch accents, resulting in a decoupling of these two kinds of accents. In the original rhythm, certain contour-pitch accents that participate in the target melody's theme are highlighted (coupled) whether or not they appear in the same serial location as in the target (*same* vs. *different* decoy). Similarly, in the new rhythm, pitch and time accents are decoupled in all melodies regardless of serial location of the relevant pitches.

Two contrasting hypotheses speak to rhythmic manipulations. One assumes that rhythm affects memory for melody simply by virtue of placement of pauses. Pauses segment each tune and can thus determine which lower order melodic groups are encoded as chunks (see, e.g., Deutsch, 1980; Dowling, 1973; Handel, 1984, 1989). However, in the present research, rhythm is manipulated in fairly constrained ways, and differential segmenting due to pause placements is precluded because the serial loci of pauses are identical for all rhythms. Thus, if melodic codes based on pause structure in familiarization do govern later melody recognition, a pause-segmentation hypothesis predicts that changing a melody's rhythm will have little systematic effect on recognition performance.

An alternative hypothesis, derived from a joint accent structure approach, holds that rhythmic highlighting boosts the accent weights of certain pitches and thus guides people's attending to the same thematic information both in familiarization and in recognition (Jones, 1987). If so, then rhythms that shift the relative locations of lengthened durations (temporal accents) within pause-based groups affect temporally selective attending because they lower accent weights. In the present context, if a new rhythm decouples pitch and time accents, it will decrease the likelihood of attending to theme-bearing, but non-adjacent, pitches. In contrast to the pause-segmentation account, this interpretation predicts that these rhythmic shifts will lower melodic discriminability.

Both the pause-segmentation hypothesis and the joint accent structure interpretation imply that melody perception depends on rhythm. However, evidence for interactions of melody with rhythm is mixed, with some report-

ing significant interactions (e.g., Boltz & Jones, 1986; Deutsch, 1980; Jones et al., 1987) and others not (e.g., Palmer & Krumhansl, 1987a, 1987b). Typically, multiple effects of rhythm on melodic structure have not been controlled, and general conclusions are therefore difficult. Because the present design represents an attempt to control some of these effects (e.g., pause placements), it sheds some light on this complex issue.

EXPERIMENT 1

Listeners were instructed to learn three different target melodies in Phase 1, a familiarization session. They were explicitly told to attend to the melody and ignore its rhythm. Furthermore, they were given no indication of a forthcoming recognition test of the tunes. In recognition (Phase 2), listeners were warned that melodies could appear in a new rhythm and were again advised to ignore rhythm and concentrate only on the melody. While the same rhythms were used in both familiarization and recognition phases, in recognition these durational patterns could be paired either with their original melodies and decoys (original rhythm) or re-paired with different melodies (new rhythm). In this way, a confounding factor of rhythmic novelty associated with rhythmic shifts in the new rhythm condition could be ruled out.

Method

Subjects

Twenty freshmen and sophomores from an introductory psychology course at Ohio State University participated in the experiment in return for course credit. All had 2-5 years of formal musical training. They were tested in groups of 1 to 4.

Design

Two phases, a learning or familiarization phase (Phase 1) and a recognition phase (Phase 2), were used. Only Phase 2 data were analyzed. Recognition accuracy was assessed using a $3 \times 2 \times 2$ mixed factorial design, for which three levels of melody (target, *same*, *different*) were crossed with two levels of rhythm (original, new). Counterbalance order (two levels) was the only between-subjects variable. The primary dependent variable was a nonparametric signal detection measure of sensitivity, A_g . The A_g metric required collapsing this design into two levels of melody (target vs. *same* and target vs. *different*), creating $2 \times 2 \times 2$ mixed factorial design for A_g and its related bias measure (B).

Stimulus Materials

Nine melodies formed three melodic sets, with each set based on a target and two decoys (*same*, *different*). All melodies were constructed of 18 square-wave tones of equivalent intensities. They were combined with different rhythms. Below, we outline melodic (pitch) sequences (targets, decoys); rhythms; and pairings of melodies with rhythms. The melodies in Sets 1, 2, and 3 are listed in the Appendix.

Melodies: Targets. Target melodies were constructed in two musical keys: F major (familiarization) and C major (recognition). To reinforce these tonalities, each target melody began and ended on its keynote pitch (i.e., either F or C), opened with prominent tonal relations (e.g., involving notes of the tonic triad), and closed with the final tonic resolving through a leading tone (i.e., E and B, respectively, in the keys of F and C; see Butler & Brown, 1984). The three target melodies differed from one another in terms of both

interval and contour-pitch relationships. Respectively, they contained four, six, and eight contour changes, plus distinctive opening segments. Figures 1a and 1d illustrate one of these; others appear in the Appendix.

Melodies: Decoys. For each target melody in a set of three melodies, two decoys were constructed in the key of C major for the recognition phase. These were: a *same* contour decoy and a *different* contour decoy. In each melody set, *same* and *different* decoys always shared the following properties with their target: (1) the same tones, with the serial locations of some changed; over the three melody sets, the number of location changes of pitches that were not at coupled accent locations were equated for *same* and *different* decoys (a total of 10 changes each), although within each melody set, *same* and *different* decoys differed, respectively: five and two changes (Set 1); two and four changes (Set 2); three and four changes (Set 3); (2) the same number of contour changes; (3) the same initial six and final three tones and their orderings (to establish the same key); (4) similar, but not identical, pitch intervals: the averages of median pitch intervals were 3, 3, and 2.66 ST for targets, *same*, and *different* decoys, respectively; (5) a majority of the same pitches marking contour accents (i.e., theme-bearing pitches); and (6) identical coupled (i.e., contour-pitch plus time) accents in target, *same*, and *different* melodies: G₄, C₄, and G₅ (Set 1); G₃, C₄, and C₅ (Set 2); C₄ and E₅ (Set 3).

Decoys differed from their respective targets with regard to when central pitches of various weights occurred relative to the melody's opening notes. With the opening tonic (Serial Location 1) as a temporal referent, time intervals associated with particular pitches at coupled accent points are identical for targets and *same* decoys but not for *different* decoys. Constraints on target and decoy construction resulted in *same* and *different* decoys differing in the total number of serial location changes: a total of 11 for *same* decoys and 16 for *different* decoys.

Rhythms. Three different recurrent durational patterns were used. All consisted of four durations, where each interval could be short (S) or long (L). Each rhythm divided the 18-tone pitch sequence into successive three-tone phrases because the fourth time interval was always a long pause. The other three intervals determined tone

durations as shown in Figure 2: SSL, SLS, and LSS. The long duration refers to an SOA (520 msec) that was always twice the length of the shorter duration SOA (260 msec). All SOAs included a 10-msec off time between adjacent tones. The pause or musical rest between recurrences of each rhythm was always 520 msec, yielding a constant higher order time period of 1,560 msec for each three-note phrase (plus pause); this structure was used for all three rhythms.

Melody-rhythm pairings. In Phase 1, each rhythm was paired with a different target melody following preliminary assumptions about accents and tonality. Pairings also relied on judgments of an independent group of four expert listeners asked to rate the tunes with respect to accents (contour and temporal) and tonality (key). Phase 1 pairings were designed to maximize the correlation of contour-pitch accents with temporal accents; they contained two or three coupled time and pitch accents within the distinctive central core of nine tones (no more than five throughout). All were judged to be in the same key.

In Phase 2, each target melody appeared in two rhythms: the original rhythm and a new rhythm. In the original rhythm, each target melody and its respective decoys were paired with the same rhythm that accompanied targets during familiarization; in the new rhythm condition, the three Phase 1 rhythms were re-paired with different target melodies and their corresponding decoys in order to phase shift pitch and time accents. Additional constraints of re-pairing for the new rhythm were: (1) A new melody-rhythm combination should not change the sense of key (preliminary ratings of experts guided these selections); (2) the new rhythm should reflect a change of two of the four durations within a group; and (3) duration and locus of the pause within the melodic string remained unchanged. Thus, the new rhythm mappings were: SSL pause → LSS pause; SLS pause → SSL pause; LSS pause → SLS pause.

Procedure

The entire experiment consisted of two phases: a familiarization phase (Phase 1) and a recognition phase (Phase 2).

Phase 1: Familiarization. Recorded instructions stressed a distinction between melody (as a pitch sequence) and rhythm (as a durational pattern). Listeners were urged to ignore the rhythm and differentiate the three target instances on the basis of the melodies only. They were not informed about the recognition phase.

Each Phase 1 trial was initiated by a warning tone (3250 Hz), followed after 2 sec by a target melody and then a 5-sec response interval. Over the 27 trials, each target appeared nine times. On each trial, the listener had to identify the target melody (using one of three letters: A, B, or C) and give a confidence rating of his or her choice (1 = most confident; 7 = least confident).

Melodies appeared with different pitch and time transpositions (applied uniformly to the whole sequence). These ensured that listeners would respond to melodic and rhythmic invariants that differentiated the targets. Such transformations commonly accompany recurrences of a given theme in music: a pitch shift up or down one octave; and a ratio time transformation that sped or slowed the melody by 2/3 or 4/3, respectively. Targets were subjected to both, one, or none of these transformations. Over the 27 trials, melodies were presented randomly, in one of two counterbalance orders, with the constraint that no more than two instances of a given target melody occur consecutively.

The Phase 1 session ended with three "hum" trials, during which the subjects covertly hummed each target after its untransformed presentation and then rated their confidence in the accuracy of their reproduction. If anyone in a group indicated low confidence, this procedure was repeated. A 15-min break followed, during which the subjects performed an unrelated task.

Phase 2: Recognition. In recognition, the subjects were told via recorded instructions that they would hear the earlier melodies plus new ones. The instructions cautioned that they attend only to the pitch sequence and ignore rhythm, because sometimes melodies would occur in a new rhythm.

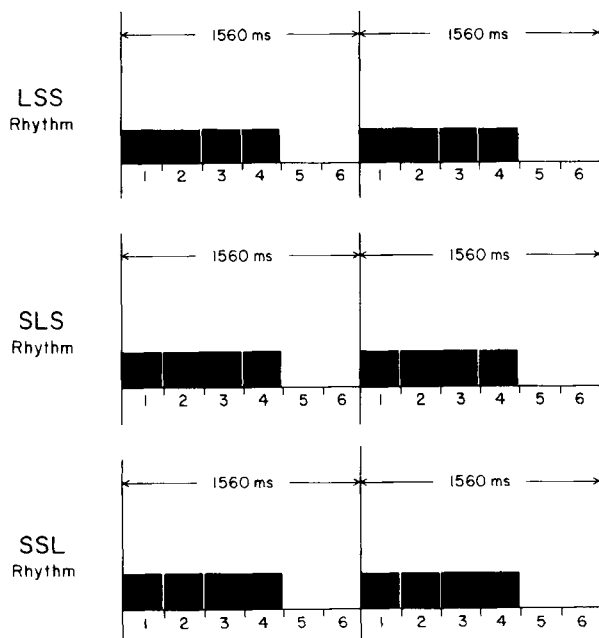


Figure 2. Three different durational patterns used in Experiment 1: LSS, SLS, and SSL. All contain six SOAs of 260 msec (S) per higher order period (1,560 msec) and a pause duration (rest) of 520 msec (L).

In this session, each trial was signaled by a 1-sec, high-pitched warning tone, followed after 2 sec by a pattern. The listener had 5 sec to indicate whether the melody was "old" (i.e., a target) or "new" (i.e., any decoy) and to register a confidence rating on the same 7-point rating scale as before.

All melodies occurred in the key of C major; none was transformed in pitch or tempo. In a total of 48 trials, the subjects received 24 targets and 24 decoys equally often in both rhythms. Four repetitions of each of the three target melodies appeared in each of the two rhythmic conditions (i.e., 12 targets per rhythmic condition). The *same* and *different* decoys each accounted for 6 trials in each rhythmic condition (two repetitions per melodic instance). Melodies were presented randomly, with the constraint that no melodic or temporal instance recur over more than 2 consecutive trials.

Scoring. Recognition was analyzed in terms of A_g and bias (B) scores. The A_g score involves a nonparametric ROC score based on computation of the trapezoidal rule (Bamber, 1975; Pollack, Norman, & Galanter, 1964) adapted by Davison and Jagacinski (1977). The A_g score estimates unbiased recognition accuracy (sensitivity) in the two-choice case, for which an A_g value of 1.00 reflects perfect discrimination and a value of .50 reflects random guessing. The bias measure roughly estimates the median confidence level score when the 7-point scale is converted to a 15-point scale ranging from 1 (sure-old) to 14 (sure-new); a score of 7.00 represents no bias. Both A_g and B scores were generated by randomly dividing the target trials into halves, and comparing a subject's response and confidence rating on the targets to the *same* and *different* decoys across each rhythmic condition. This analysis essentially collapses the trilevel melody factor into two levels, subsequently referred to as target:*same* and target:*different*. Supporting analyses involve accuracy scores, namely hit rates (proportion correct to targets) and correct rejections (proportion correct to decoys; note that the false alarm rate is simply $1 -$ the proportion correct to decoys).

Results

For all dependent measures, analyses involving the presentation order of stimuli showed this counterbalance variable to be nonsignificant. Thus all of the presented results have been collapsed across this factor.

Sensitivity/Accuracy

Variations in melodic structure systematically affected discriminability. The subjects more often confused *same* decoys with targets than they did *different* decoys. Table 1 presents mean A_g values as a function of melodic condition (target:*same* and target:*different*) as well as rhythm (original vs. new). The A_g metric is based on comparing performance of targets (signals) with a set of decoys (noise). When the set involved *same* decoys as noise, the mean A_g was .719, whereas when *different* decoys supplied noise, the mean A_g was .835 [$F(1,18) = 16.25$, $MS_e = 16.620$, $p < .001$].

Table 1
Mean A_g and Bias Scores for Experiment 1

Rhythm	Melody				Means	
	Target vs. <i>Same</i> Decoy		Target vs. <i>Different</i> Decoy			
	A_g	Bias	A_g	Bias	A_g	Bias
Original	.823	5.60	.877	5.80	.850	5.70
New	.615	7.75	.794	9.15	.704	8.45
Means	.719	6.68	.835	7.48		

Table 2
Mean Proportion Correct for Experiment 1

Rhythm	Melody			Means
	Target	<i>Same</i> Decoy	<i>Different</i> Decoy	
Original	.864	.680	.798	.781
New	.584	.680	.890	.718
Means	.724	.680	.844	

Rhythmic shifts also affected performance. Although pause segmentation is the same for original and new rhythms, subjects were better at discriminating melodies in the former. As measured by A_g , recognition was significantly better in the original rhythm than in the new rhythm [mean $A_g = .850$ vs. $.704$; $F(1,18) = 14.43$, $MS_e = 29.556$, $p < .0025$].

Melody recognition is also differentially affected by rhythm, as is evidenced by a significant interaction of melody with rhythm [$F(1,18) = 4.48$, $MS_e = 17.77$, $p < .05$]. Disproportionately poor performance occurred when the subjects had to discriminate targets from *same* decoys in a new rhythm (mean $A_g = .615$ vs. $.794$, $.823$, and $.877$ in the other conditions). Poor discriminability can come from either low target recognition accuracy or from errors to *same* decoys or both. The accuracy data (Table 2) suggest that the culprit here is poor target identification levels in the new rhythm. Error rates to *same* decoys (i.e., $1 -$ proportion correct; namely, false alarms) are identical in the two rhythms. Taken together, these findings tell us two things: (1) The new rhythm renders a melodic theme less attention-getting and thus increases identification errors in the target melody; and (2) the original rhythm makes discrimination of targets from *same* and from *different* decoys roughly similar, a fact that argues against the possibility that *different* decoys are inherently more discriminable from targets than *same* decoys because they contain distinctive interval differences.

An interaction of melody with rhythm in proportion correct scores is also significant [$F(2,36) = 25.30$, $MS_e = .0148$, $p < .0001$]. Although accuracy is lower with *same* decoys than with *different* decoys in both rhythms, post hoc analyses (Tukey's *HSD*) show that these differences were significant only in the new rhythm. We will return to this point.

Bias

A bias score of 7 reflects unbiased judgments, while B scores larger than 7 indicate bias for saying "new." Table 1 shows mean B scores as a function of the melody and rhythm conditions.

Rhythm biases judgments. People tend to judge any melody (target or decoy) to be familiar (i.e., "old" with mean $B = 5.70$) when it appears in the original rhythm. Similarly if it appears in the new rhythm, they are more likely to judge a melody "new" [mean $B = 8.45$; $F(1,18) = 21.75$, $MS_e = 6.96$, $p < .0005$]. This finding is not surprising. It suggests that changes in accuracy arise partly from the biasing influence of rhythm.

Discussion

Clearly, both melodic and rhythmic structure affect delayed melody recognition. Listeners' memories of relatively long, rhythmically patterned tunes are systematically influenced by the melodic variations associated with the two kinds of decoys used, thus substantiating the influence of contour timing information on melodic discrimination. Furthermore, even when warned to ignore rhythm, listeners cannot do this. Shifts in rhythm significantly lower listeners' abilities to distinguish targets from decoys, despite the fact that pause structure is held constant. Although these findings are consistent with a joint accent structure analysis, they do not conclusively establish that accent coupling, which is preserved only by the original rhythm, is responsible for these effects. This issue is pursued in Experiment 2.

The finding that average listeners are more often fooled by *same* than by *different* decoys extends previous findings regarding effects of contour, which were based on shorter melodies and briefer retention periods (e.g., Dowling & Fujitani, 1971; Monahan et al., 1987). Here, contour changes are reinforced by tonally significant pitches and thus effectively instantiate a memorable theme, which, for these listeners, lasts over a substantial retention interval.

It is interesting that differences among *same* and *different* decoys are more marked in the new rhythm than in the original one. In fact, in the original rhythm, *same* and *different* decoys are roughly equivalent in discriminability, which requires an explanation. Because thematically relevant pitches are presumably weighted more in the original rhythm, one might expect that listeners would take *same* decoys to be targets more often in this condition. In fact, such a finding did obtain in Jones et al. (1987), where listeners made disproportionately more false alarms to *same* than to *different* decoys in the original rhythm. Why didn't preserving the original rhythm boost error rates to *same* decoys in the present case? One explanation involves the fact that in the present study, rhythms with accent coupling were used, whereas in the Jones et al. experiments, they were not. It is possible that this highlighting serves more to facilitate discrimination of differences between a decoy and its target than to enhance their similarities. Another explanation also concerns the rhythms used. Jones et al. employed rhythms in which durational patterns were more heterogeneous as a set than those in the present research. Thus, re-pairing of rhythms in that study could have heightened the influence of any single distinctive rhythm on melody perception. If so, listeners in the Jones et al. study might have been more confused by *same* decoys when they appeared in the target's original rhythm as opposed to a very dissimilar one. We pursued the idea of rhythmic similarity in Experiment 2.

EXPERIMENT 2

In Experiment 2, we relied on the same design and strategy as in Experiment 1 to pursue two questions

about the effect of rhythmic highlighting on long-term memory for melodies. The first question concerns effects of rhythmic similarity when listeners confront melodies in novel rhythms. The second explores the degree to which rhythmic similarity effects, if present, depend on the listener's familiarity with the target melodies in their original rhythms.

The term *rhythmic similarity* refers to the extent to which a new rhythm shares relevant temporal properties of the melody's original rhythm. For example, if accent coupling contributes to the superiority of the original rhythm in Experiment 1, then similar rhythms that preserve such aspects of familiar joint accent structure should also enhance melodic discriminability in Experiment 2.

We explore this by manipulating rhythmic similarity in terms of the way a rhythm fits with a melody as suggested by a joint accent structure analysis. Similarity depends here on the number and the kind of tone durations changed by a rhythmic shift (from Phase 1 to Phase 2). A new set of Phase 2 rhythms was used to realize these criteria in Experiment 2. Although distinctly different from the Phase 1 rhythms, when paired with Phase 1 melodies, these rhythms provided different degrees of similarity. Table 3 shows two different similarity mappings of Phase 1 and Phase 2 rhythms: *similar* and *dissimilar* rhythmic shifts. A *similar* rhythm involves changing two time intervals per pause-defined group, including the pause; a *dissimilar* rhythm involves changing all intervals in each pause-defined group. For example, the shift of LSS long pause . . . to LLS short pause . . . is a *similar* rhythm shift, whereas changing it to SLL short pause . . . is a *dissimilar* rhythm shift. In addition, *similar* rhythm conditions do not phase shift pitch and time accents, whereas *dissimilar* rhythm conditions do. Consequently, *similar* rhythm conditions preserve accent coupling and *dissimilar* rhythm conditions do not (see Table 3). In this way, rhythmic similarity is not defined independently of what a rhythm does to a melody and its pitch accents; rather, it is assessed in terms of commonalities of pitch/time accent patterns. These constraints permit relevant comparisons of performance in the *similar* and *dissimilar* rhythm conditions to that in the original and new rhythm conditions, respectively, of Experiment 1.

The similarity manipulation captures certain composing techniques whereby listeners are made to experience

Table 3
Rhythmic Shift Mappings for Experiment 2

Similar Rhythm Condition	
Phase 1	Phase 2
S S L*	L* S L ^s
S L* S	S L* L ^s
L* S S	L* L ^s S
Dissimilar Rhythm Condition	
Phase 1	Phase 2
S S L*	L* L ^s S
S L* S	L* S L ^s
L* S S	S L* L ^s

*Primary temporal accent. ^sSecondary temporal accent.

different degrees of thematic reminiscence, depending on the rhythm in which some melody or its variation recurs within a larger composition. We anticipate, therefore, that both kinds of rhythmic shifts in Experiment 2 will lower a listener's discrimination of target melodies relative to its original rhythm. However, the *similar* rhythm shifts preserve higher order aspects of a tune's joint accent structure such as its accent coupling properties, and since these are assumed to be more prominent in guiding attending and remembering, the *similar* rhythm condition should yield better target recognition than the *dissimilar* rhythm condition, much as the original rhythm did in Experiment 1. Thus, the similarity manipulations allow us to consider what changes in a joint accent structure tend to preserve target recognition and what ones do not.

Relatedly, we can also determine whether the general context provided by new rhythms affects listeners' responses to thematic variations instantiated by *same* decoys. Data from Experiment 1 suggest that *same* decoys are not significantly more confusing than *different* decoys when both appear in the target's original rhythm. However, novel rhythms may encourage listeners to focus largely on higher order properties of the joint accent structure; if so, *same* decoys may be more often mistaken for targets in the *similar* rhythm conditions than in *dissimilar* conditions. While both *similar* and *dissimilar* rhythm conditions introduce joint accent structure changes, the former preserves important higher level relations involving coupled accents.

Finally, in Experiment 2, we also looked at perceptual learning. Listeners' familiarity with targets in their original rhythm was systematically varied across two separate studies (Experiments 2A and 2B). Common sense led to the expectation that performance should be better with more Phase 1 training. However, we were also interested in discovering whether differential effects of rhythm or melody variables would appear. That is, do people immediately respond to certain properties of a joint accent structure associated with more prominent accents (i.e., coupled accents)? If so, they should display disproportionately high performance in *similar* rhythm conditions even with relatively unfamiliar tunes.

Method

The method of Experiment 2 was identical to that of Experiment 1, with the following exceptions:

Subjects

Ohio State University freshmen and sophomores were assigned randomly to two counterbalance orders in each of two experiments. In Experiment 2A, 16 subjects served in each order ($N = 32$); in Experiment 2B, 13 subjects served in each order ($N = 26$).

Design

The design for each experiment was identical to that of Experiment 1, provided that the rhythm variable is taken to be the rhythmic similarity manipulation.

Experiment 2A: High familiarity. This study was identical to Experiment 1, with the exception that the 48 Phase 2 trials involved

new rhythms based on combinations of two L durations and one S tone duration, plus a pause of S duration. Phase 1 consisted of 27 trials.

Experiment 2B: Low familiarity. This study was identical to Experiment 2A, with the exception that fewer familiarization trials were used. In Phase 1, participants heard only one presentation of each target melody in its rhythm and then received the "hum" trials. They received no melody-identification training trials. This study was conducted approximately 6 months after Experiment 2A had been completed.

Stimulus Materials

Phase 2 rhythms are presented in Table 3. The SOAs for the two L durations remained 520 msec with 10 msec off time; the S tone duration and pause were 260 msec. Loci of temporal accents were determined both by conventional analyses of primary and secondary accents and on the basis of judges' ratings of these rhythms, both in monotone and target melody contexts. Although ratings were somewhat variable, the locations selected generally qualified as either primary or secondary temporal accents.

The mapping rules used to define *similar* and *dissimilar* rhythm conditions, given Phase 1 rhythms, are shown in Table 3. They observed the following criteria: *similar* rhythm conditions—changed two durations per recurrent rhythmic group (one tone and the pause), while preserving identical serial locations of temporal accents in both Phase 1 and Phase 2 rhythms. In two of the three *similar* rhythms, this involved primary accents; in the third, a secondary accent was involved (a mapping involving two durational changes, which always preserves the temporal accent, was not possible with this rhythmic set); *dissimilar* rhythm conditions—over all four durations (per group), reverse L duration and S durations. A by-product of this was that the resulting Phase 2 rhythms always phase shifted the serial location of the primary temporal accent of the Phase 1 rhythm by a time constant. As in Experiment 1, both mappings preserved serial locations of pauses (musical rests) within melodies.

Results

The results of Experiments 2A and 2B, collapsed over counterbalance order (a nonsignificant variable), are presented in Tables 4 and 5. Initially, these data will be discussed separately, because they arise from experiments conducted 6 months apart. Subsequently, the performance with familiar tunes (2A) will be compared with the performance with unfamiliar ones (2B).

Table 4
Mean A_g and Bias Scores as a Function of
Target Familiarity in Experiment 2

Rhythm	Melody					
	Target vs. Same Decoy		Target vs. Different Decoy		Means	
	A_g	Bias	A_g	Bias	A_g	Bias
High Familiarity: Experiment 2A						
<i>Similar</i>	.713	5.56	.834	6.66	.773	6.11
<i>Dissimilar</i>	.649	7.19	.778	8.16	.713	7.67
Means	.681	6.37	.806	7.41		
Low Familiarity: Experiment 2B						
<i>Similar</i>	.714	6.04	.733	7.27	.724	6.65
<i>Dissimilar</i>	.665	5.58	.756	9.31	.710	7.44
Means	.689	5.81	.744	8.29		

Table 5
Mean Proportion Correct as a Function of
Target Familiarity in Experiment 2

Rhythm	Melody			Means
	Target	Same Decoy	Different Decoy	
High Familiarity: Experiment 2A				
Similar	.810	.594	.786	.730
Dissimilar	.627	.667	.818	.704
Means	.718	.630	.802	
Low Familiarity: Experiment 2B				
Similar	.686	.587	.702	.658
Dissimilar	.606	.535	.830	.657
Means	.646	.561	.766	

Experiment 2A: High Familiarity

The recognition performance of listeners with substantial familiarity with the target tunes is summarized in Tables 4 (mean A_g and B) and 5 (mean proportion correct).

Sensitivity/accuracy. Relative to Experiment 1, novel rhythms did reduce the listeners' abilities to discriminate melodies somewhat. However, melodic structure had comparable effects in both experiments. Listeners were poorer at distinguishing targets from *same* decoys than from *different* decoys [A_g values of .681 vs. .806; $F(1,30) = 16.86$, $MS_e = 29.787$, $p < .0005$]. Rhythmic similarity also had a significant effect on performance; shifting melodies to a similar rhythm produced better discriminability than shifting them to a dissimilar one (see Table 4) [$F(1,30) = 14.38$, $MS_e = 7.879$, $p < .001$]. Nevertheless, in both rhythms, the listeners were significantly above chance levels in distinguishing targets from decoys (i.e., chance A_g is .50).

Perhaps the most important finding is that the interaction of rhythm with melody observed for discriminability scores in Experiment 1 disappeared in this study. A comparison of Tables 1 and 4 explains why. Although the listeners were best with *similar* rhythms, relative to Experiment 1 levels they were somewhat poorer in distinguishing targets from *same* decoys in rhythms with accent coupling (i.e., *similar* vs. original rhythms). This lack of interaction in A_g is more in line with the results of Jones et al. (1987).

Failure to find the interaction of A_g scores as in Experiment 1 derives from two sources, as substantiated by accuracy scores in Table 5. First, as anticipated, when *same* decoys appeared in novel, but *similar*, rhythms, they indeed fooled people more than in novel, but *dissimilar*, rhythms. As predicted, error rates to decoys in this study were highest to *same* decoys in the *similar* rhythm condition. The *same* decoys were significantly more confusing than *different* decoys not only in the *dissimilar* rhythm condition but, in contrast to Experiment 1, also in the *similar* rhythm condition (Tukey $HSD = .156$, $p < .01$). The second contributing factor was mentioned above: Target identification accuracy in *similar* rhythm conditions was slightly poorer than in the original rhythm of Experiment 1. Thus, while discriminability scores do

not show an interaction of melody with rhythm, accuracy scores do [$F(2,60) = 9.92$, $MS_e = .0313$, $p < .0005$]. Contributing to this effect is the fact that although correct identifications of *same* decoys rose in the *dissimilar* rhythm condition, target identification accuracy dropped in these rhythms.

Finally, accuracy measures reflect a combination of biasing influences and discriminability. In Experiment 2A, some of the changes in accuracy levels as a function of rhythm arose from its biasing potential.

Bias. Table 4 shows mean B scores as a function of changes in melody and rhythm. The bias findings replicate those of Experiment 1, in that rhythm has the primary influence on performance. Melodies appearing in similar rhythms tend to evoke "old" responses, and those in dissimilar rhythms to evoke "new" responses [$F(1,30) = 9.56$, $MS_e = 8.18$, $p < .005$]. The most unbiased performance levels involved the set of targets and *different* decoys in the *similar* rhythm condition and the set of targets and *same* decoys in the *dissimilar* rhythm condition.

Experiment 2B: Low Familiarity

The performance of listeners who had less familiarity with target tunes also is summarized in Tables 4 (mean A_g and B scores) and 5 (mean proportion correct scores).

Sensitivity/accuracy. The pattern of A_g scores with less familiar tunes bears some resemblance to that found with familiar ones, but the effects of melody and rhythm are more modest with no statistically significant impact (Table 4). Two aspects of these null findings deserve comment: (1) Listeners are not disproportionately better in the *similar* rhythm conditions; and (2) they are relatively poor overall in differentiating *different* decoys from targets.

Supplementing these findings, the accuracy scores indicate that the listeners did, in fact, err more often with *same* than with *different* decoys in both rhythms [$F(2,48) = 11.47$, $MS_e = .048$, $p < .0001$]. However, rhythm continued to have no overall effects on accuracy (the mean proportions correct for *similar* and *dissimilar* rhythm conditions were roughly equivalent). With less familiar tunes, similar rhythms actually produce an improvement in listeners' chances of spotting *same* decoys relative to dissimilar rhythms; accuracy levels to *same* decoys were near chance in the *dissimilar* rhythm condition. However, *similar* rhythm conditions also decreased the listeners' chances of spotting *different* decoys as such relative to the *dissimilar* rhythm conditions. A significant interaction of rhythm with melody resulted [$F(2,48) = 7.72$, $MS_e = .022$, $p < .002$]. These error rates appear to reflect a combination of biasing influences of contour-pitch accent structure and rhythm.

Bias. In contrast to listeners familiar with targets, these listeners were biased by differences in melodic structure [$F(1,24) = 25.26$, $MS_e = 6.33$, $p < .0001$]. The *same* decoys evoked more "old" judgments than did the *different* decoys. The mean bias for the target:*same* set was $B = 5.81$, whereas that for the target:*different* set was much higher ($B = 8.29$). Also in contrast with Experi-

ment 2A, rhythm only modulated these effects, making them most evident in the *dissimilar* rhythm conditions; it had no overall influence. This interaction of melody and rhythm is significant [$F(1,24) = 5.12$, $MS_e = 7.94$, $p < .05$]. Post hoc comparisons indicated that the difference within the *dissimilar* rhythm condition was significant (Tukey *HSD* = 2.09, $p < .05$). Thus, the bias measures fleshed out effects of rhythm and melody on accuracy scores that were considered earlier.

Experiment 2A versus 2B: Familiarity Effects

Listeners who were more familiar with target tunes were not substantially better overall in differentiating them from decoys in recognition. The main effect for the familiarity effect on A_g scores was nonsignificant ($F = 1.18$, $p < .28$). Furthermore, as a variable in the combined A_g analysis, familiarity did not significantly qualify the effects of either rhythm or melody. Not surprisingly, although both melody and rhythm had significant effects in this combined analysis [$F(1,54) = 16.89$, $MS_e = 27.614$, $p < .0001$, for melody; $F(1,54) = 7.25$, $MS_e = 10.443$, $p < .01$ for rhythm], neither interacted with familiarity level (Experiment 2A vs. 2B). In fact, the listeners with different degrees of target familiarity were virtually identical in their abilities to distinguish *same* decoys from targets in *similar* rhythms (mean A_g scores of .714 vs. .713). This finding, together with the fact that a combined analysis yielded no significant interaction of rhythm or melody with familiarity, suggests that some immediate advantages accrue to preserving rhythmic and pitch-contour similarities. Nevertheless, on the average, these early differences are slight compared with those observed with familiar tunes.

Where do these two groups of listeners differ, if they do? Overall accuracy improves significantly with familiarity (from proportion correct of .658 to .717) [$F(1,54) = 5.77$, $MS_e = .0528$, $p < .02$]. The most striking change arises from improvements in target recognition in *similar* rhythm conditions, and this contributes to a significant three-way interaction of familiarity level with melody and rhythm [$F(2,108) = 4.56$, $MS_e = .027$, $p < .025$]. The accuracy and bias scores in both combined and separate analyses suggest that listeners who are less familiar with target melodies are more biased overall by melodic differences among to-be-recognized tunes and that they come to rely more heavily on rhythm with familiarity. Although large initial effects of rhythm were not evident, rhythm did exert some early influences on the listeners' sensitivity to pitch contour. Furthermore, these effects seemed to intensify with the listeners' experience. This was evident in the listeners' relative performance on targets and *same* decoys as a function of familiarity: Error rates declined with targets in the *similar* rhythm condition, whereas they did not with *same* decoys. In fact, improvement with *same* decoys as a function of familiarity occurred largely with the *dissimilar* rhythm conditions, in which proportions correct climbed to .667 from .535. This pattern of findings suggests that there is an immedi-

ate sensitivity to pitch contour information that can persist if it is rhythmically reinforced.

Discussion

People learn to extract from relatively long melodies enough information about their pitch structure to recognize them in novel rhythms, especially if these rhythms share certain temporal properties with their original rhythms. This experiment sheds light on three aspects of this phenomenon. Two concern the way rhythmic similarity affects recognition of targets and decoys, respectively. The third is related to listeners' differential use of rhythm with perceptual learning (familiarity).

People recognize targets best when these tunes reappear in similar rhythms. While they are less adept with novel rhythms than when such tunes appear in their original rhythm, people nonetheless correctly recognize targets around 80% of the time (relative to 86% in the original rhythm). Thus, certain rhythmic shifts can support relatively high levels of theme recognition. Undoubtedly, a key element in this effect is the novel rhythm's accent coupling potential.

Design constraints in Experiment 2 meant that the *similar* rhythm conditions preserved not only a rhythm's accent coupling potential but also more tone duration pairings than did *dissimilar* rhythm conditions. However, an explanation of the rhythmic similarity effect based strictly on the number of durational changes cannot suffice. There is evidence that the kind of temporal change (coupled vs. uncoupled) matters. First, differences in target accuracy due to differences in the number of durational changes were modest when accent coupling was held constant (*similar* rhythm vs. the original rhythm in Experiment 1). Second, across all rhythm conditions (Experiments 1 and 2A), performance should have declined with increases in the number of durational changes associated with a shift if this was critical; this did not happen. Thus, we conclude that an important component of rhythmic similarity effects on theme recognition involves accent coupling. In the context of novel rhythms, the time patterns that continue to temporally highlight a familiar theme are most likely to evoke a recognition response.

One general influence of placing melodies in novel rhythms may be that it encourages listeners to rely more on temporal relationships among prominent accents within a joint accent structure. If so, we might expect responses to decoys to show systematic effects of rhythmic similarity manipulations. They do. Rhythmic similarity not only supports better target recognition but it also boosts the chances that listeners will mistake a *same* decoy for a target. This finding confirms that of Jones et al. (1987). It is also consistent with a joint accent structure account of rhythmic similarity in music, which implies that the effective similarity of a durational pattern depends on the way in which it fits with a melodic one, given the context in which both are experienced.

The findings of Experiment 2A are consistent with those of Experiment 1, in that listeners are better at differen-

tiating targets from *different* decoys (as opposed to *same* decoys) in both rhythms. However, these trends are not so evident with less familiar melodies (Experiment 2B). Consequently, one might conclude that contour-pitch manipulations have minimal impact on listeners' memories of little-heard tunes, a conclusion consistent with other findings involving relatively long retention periods (Dowling & Fujitani, 1971; Edworthy, 1985). However, in the present case, such a conclusion is premature.

In previous work, pitch contour has not been systematically manipulated as it has here, nor have rhythm and familiarity been manipulated jointly in long-term retention tasks. In the present case, there is evidence that these pitch contours are remembered for substantial time intervals. For example, listeners are better at differentiating little-heard targets from *different* decoys than from *same* decoys in the *dissimilar* rhythm conditions (mean A_d is .665 with *same* decoys and .756 with *different* decoys). Although the overall interaction of melody with rhythm was not significant in this case, the difference is a sizable one that is buttressed by error rate analyses. Error rates indicate that these listeners judged the *same* decoys to be targets over 41% of the time in *similar* rhythm conditions and over 46% of the time in the *dissimilar* rhythm conditions; corresponding error rates to *different* decoys were substantially lower, hovering around 30% and 17% respectively! Thus, even after long retention intervals, a greater proportion of errors with less familiar tunes is due to contour-related confusions than is the case with familiar tunes. Although it is true that these errors indicate a biasing influence of higher order melodic structure, it is significant that this bias is specific to the melodic variation involved and that it persists over long time periods.

Nevertheless, a word of caution is appropriate in drawing conclusions about contour effects from such designs, because there is always the possibility that listeners respond to some distinctive pitch interval change(s) in one type of decoy (*same* or *different*). However, at least data from Experiment 1 indicate that under optimal conditions (original rhythm), the *same* and *different* decoys are not vastly different in discriminability, as might be expected if listeners relied solely on some distinctive interval difference to differentiate targets from decoys.

Finally, what about differential effects of rhythm on perceptual learning? Disproportionate benefits due to the *similar* rhythm condition are not evident early in learning. Instead, rhythm has a more limited early influence. However, rhythm and accent coupling clearly contribute to initial biases and ultimately help to shape perceptual learning. One scenario is that perceptual learning involves an early and crude responsiveness to highlighted pitch accents, and that with experience listeners abstract higher order time relations among these pitches. In this way, accent coupling may facilitate learning about "when" theme-bearing information occurs. If this interpretation is correct, recognition error rates for targets and *different* decoys in the *similar* rhythm conditions should decline with prac-

tice, because in these cases listeners can reliably detect differentiating melodic information at attended-to serial locations. This is the case. This interpretation also implies that if target identification depends on abstraction of temporal relationships among highlighted contour-pitch accents, then error rates to *same* decoys in the *similar* rhythm will not decline with familiarization training. And they do not.

GENERAL DISCUSSION AND CONCLUSIONS

Listeners' sense of a familiar melodic theme after a substantial delay depends heavily upon the way a new rhythm highlights a melody's contour-related pitches. Particularly with fairly familiar tunes, reinstatement of rhythmic highlighting of some thematic information makes it more identifiable in both targets and decoys.

Perhaps these findings are not surprising. Intuitively, the *same* decoys represent lawful variations of the target melody's theme. But it is useful to discover that, depending on the rhythmic context, listeners mistake *same* decoys for targets over 40% of the time and, moreover, that these error rates do not decline as listeners become more familiar with the target. Together with findings of Jones et al. (1987), these data extend Dowling's (1978) hypothesis in showing that not only is contour-related information abstracted early in learning, but it is retained over substantial time periods.

As it was manipulated here, rhythm influenced not only the recognizability of a target melody but also the extent to which different variations of it (decoys) fooled listeners. Together, these findings imply that a pause-based encoding account of rhythm is too simple. With pause structure held constant, listeners are better at discriminating familiar targets from decoys when both appear in rhythms identical or similar to the original rhythm of the target. Performance depended on the serial loci of temporal accents within pause-based groups.

All novel rhythms take some toll on melody recognition; even changing a few durations within a pause-based group can hurt. Thus, target accuracy in Experiment 2 is somewhat poorer in the *similar* rhythm conditions than in the original rhythms (Experiment 1), even though pause segmentation and accent coupling are preserved in both. One reason stems from the fact that rearranging any duration within a rhythmic figure inevitably affects relative timing among *all* pitch accents (e.g., those from pitch skips etc.), not simply those involving contour change. The present design only manipulated the relative timing of pitch accents related to pitch contour; however, rhythmic shifts that modify timing of other pitch accents in a target should also lower its recognizability (Boltz & Jones, 1986; Monahan et al., 1987).

These data also speak to the perceptual independence of melody and rhythm. Since absence of interactions is often taken as evidence for independence, it is clear that there is no simple solution to this issue. Evidence can be adduced for both independence (Experiment 2) and lack

of it (Experiment 1), even with regard to the same dependent measure (A_g). Furthermore, on another level, it is also evident that in these tasks listeners who were explicitly instructed to ignore rhythm and pay attention only to pitch changes simply could not do this. The main effect of rhythm on recognition of melodies with identical pause punctuations, as indexed by all dependent measures, tells us how difficult it is for average listeners to focus on melodic information independently of rhythm. Perhaps the most plausible approach is one that maintains that presence or absence of interactions depends both on the way melodic and rhythmic structures fit together to determine a joint accent structure and on how listeners abstract and use its relational properties within some larger context.

Finally, these findings have been interpreted in terms of the way temporal context, summarized by joint accent structure, guides attending. With practice, coupled accents within an accent-time hierarchy come to command attending to temporal loci of nonadjacent events (Jones, 1985, 1987; Jones & Boltz, 1989). Others also address temporal context effects, but do so with clock models where various accents are assumed to occur with fixed time periods (e.g., Povel & Essens, 1985; Monahan et al., 1987).

However an alternative, noncontextual, account of rhythmic influences is possible. It argues that coupling "works" because temporal accents offer more time to process pitch information (Idson & Massaro, 1976; Povel & Okkerman, 1981). Although this may be part of the story, it is unlikely to be the whole story, because all time intervals associated with pitches are above thresholds suggested for improvements in pitch recognition with time (i.e., 70-250 msec).

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NOTES

1. A musical *key* in tonal Western music refers to a diatonic set of seven pitches that conforms to constraints on successive pitch intervals of the form 2ST, 2ST, 1ST, 2ST, 2ST, 2ST, 1ST, where ST refers to a semitone pitch interval. The semitone is the smallest pitch division of the octave in Western music; it is logarithmically defined as a constant ratio between two frequencies of 1.059... according to equal temperament tuning. Melodic structure in tonal music builds on special diatonic relationships; among these are ones involving the psychological anchoring function of the keynote or tonic (e.g., the tonic is C in the C major scale, which consists of C D E F G A B C').

2. Some have used the term *pitch inflection* to refer to accents associated with pitch contour (Monahan et al., 1987). Their use differs from the present definition of *contour-pitch accents* in two ways: (1) They imply an interval-plus-pitch direction change; and (2) they do not conceive of differential accent weights as a function of local versus global pitch peaks.

3. If central pitches themselves are taken as the referent for establishing interval time relations among the contour-pitch accents, then some *different* decoys actually change the temporal order of these accents as they appear in their targets. However, the general rationale involved changing the relative time of prominent central pitches relative to the fixed openings segment. This is most accurately formalized as a $\pm \Delta t$ change between two tone onsets. In terms of a joint accent structure analysis, each pitch is assigned an accent weight, which in turn defines its level in an accent/time hierarchy. More prominent central pitches contribute to heavier accent weights, which are, in turn, correlated with longer time intervals in this analysis (Jones, 1976, 1987). Thus, changing the serial location of any pitch can also modify relative time properties of an accent/time hierarchy (Jones, 1990).

Appendix

Stimuli Used in All Experiments

Melody Set 1

Target:	$C_4^+ E_4^+ G_4^- G_4^+ C_5^+ E_5^+ F_5^+ G_5^+ C_5^- B_4^- G_4^+ A_4^- E_4^- C_4^+ D_4^+ F_4^- B_3^+ C_4^+$
Same decoy:	$C_4^+ E_4^+ G_4^- G_4^+ C_5^+ E_5^+ F_5^+ G_5^+ C_5^- B_4^- G_4^+ A_4^- E_4^- C_4^+ D_4^+ F_4^- B_3^+ C_4^+$
Different decoy:	$C_4^+ E_4^+ G_4^- G_4^+ C_5^+ E_5^- B_4^- G_4^+ C_5^+ F_5^+ G_5^+ A_4^- E_4^- C_4^+ D_4^+ F_4^- B_3^+ C_4^+$

Phase 1 Rhythm: SLS

Experiment 1 rhythms, Phase 2	Experiment 2 rhythms, Phase 2
Original: SLS	Similar rhythm: SLL
New: SSL	Dissimilar rhythm: LSL

Melody Set 2

Target:	$C_4^+ E_4^+ G_4^- G_4^+ E_4^+ G_4^- D_4^- A_3^- G_3^+ C_4^- B_3^+ C_4^+ A_4^+ B_4^+ C_5^- F_4^- B_3^+ C_4^+$
Same decoy:	$C_4^+ E_4^+ G_4^- G_4^+ E_4^+ G_4^- D_4^- B_3^- G_3^+ C_4^- A_3^+ C_4^+ A_4^+ B_4^+ C_5^- F_4^- B_3^+ C_4^+$
Different decoy:	$C_4^+ E_4^+ G_4^- G_4^+ E_4^+ G_4^- A_4^+ B_4^+ C_5^- C_4^- B_3^+ C_4^+ D_4^- A_3^- G_3^+ F_4^- B_3^+ C_4^+$

Phase 1 Rhythm: SSL

Experiment 1 rhythms	Experiment 2 rhythms, Phase 2
Original: SSL	Similar rhythm: LSL
New: LSS	Dissimilar rhythm: LLS

Melody Set 3

Target:	$C_4^+ E_4^+ G_4^- G_4^+ E_4^- D_4^- C_4^+ G_4^+ C_5^+ E_5^- D_5^- B_4^- F_4^- E_4^- D_4^- G_3^- B_3^+ C_4^+$
Same decoy:	$C_4^+ E_4^+ G_4^- G_4^+ E_4^- D_4^- C_4^+ F_4^+ B_4^+ E_5^- D_5^- C_5^- G_4^- E_4^- D_4^- G_3^- B_3^+ C_4^+$
Different decoy:	$C_4^+ E_4^+ G_4^- G_4^+ E_4^- D_4^- C_4^+ F_4^+ G_4^+ B_4^+ C_5^+ D_5^- E_5^- E_4^- D_4^- G_3^- B_3^+ C_4^+$

Phase 1 Rhythm: LSS

Experiment 1 rhythms	Experiment 2 rhythms, Phase 2
Original: LSS	Similar rhythm: LLS
New: SLS	Dissimilar rhythm: SLL