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The Development of Perception of Interleaved Melodies and Control of Auditory Attention

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Between the ages of 5 and 10, children gain skill in focusing expectancies and attention. We asked children in that age range (and adults) to discern familiar target melodies whose notes were temporally interleaved with distractor notes. Targets varied in perceptual salience: the most hidden targets were interleaved with distractors of the same pitch range, loudness, and timbre, whereas the most salient targets differed in those dimensions from their distractors. Targets either retained their familiar "straight" form or wandered in pitch. Wandering targets preserved contour (ups and downs) but not pitch intervals, and either remained within the original key ("tonal") or deviated from it ("atonal"). Distractors were drawn from the original key ("tonal") or a distant key ("atonal").

Performance improved with age and experience, was better with salient (vs. hidden) targets, and better with straight (vs. wandering) targets. All but the 5- and 6-year-olds found salient targets easier with tonal distractors and hidden targets easier with atonal distractors. Only the youngest children found same-timbre distractors outside the pitch range of the target as disruptive as same-timbre distractors within that range. By 7–8 years of age, children were able to focus attention within the target pitch range to follow straight targets, indicating the focusing of attention in pitch; and by 9–10 years of age they were able to discern clearly the most hidden straight targets, demonstrating a rhythmic control of expectancies.

We know that during the elementary school years children generally develop their skills for selectively focusing attention. For example, Doyle (1973) found that children between the ages of 8 and 14 years improved their performance in a word listening task, becoming more skilled in focusing attention on targets and in ignoring distractors. Geffen and Sexton (1978) found that between 7 and 10 years of age children improved their ability both in focusing auditory attention on target words and in handling a divided attention task. However, there is little specific evidence concerning the development of the control of auditory

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attention—particularly aiming attention in terms of dimensions of sound such as pitch.

Music provides a useful domain in which to study the development of auditory perception and attentional control. Music is like speech in having a natural ecological validity and in being involved in human development from infancy. Children throughout the world sing songs, listen, and dance, and so music is a very natural medium with which to explore children's auditory attention. As Odom (1982) has pointed out, it is especially important in studying the development of attention to use stimulus information that the younger subjects view as relevant. Music is simpler than speech in certain respects—there is not the complication of semantic meaning, and its temporal patterning is easier to describe. This makes it easier to specify the fine-grained temporal structure of auditory targets and thus study in detail the temporal control in cognitive processes required to perceive them.

In addition to developing cognitive skills in general, children between 5 and 10 years old develop specific skills involved in music listening. They develop precision in their memory representations of songs, as well as a progressive elaboration of the tonal scheme (Krumhansl & Keil, 1982). Perceptual experience leads them to be responsive to the invariant patterns of tonality that operate across melodies in a culture, in Western music epitomized in the major scale pattern. Numerous studies have demonstrated changes with age and experience in the importance of stimulus factors such as melodic contour, pitch intervals, tonality, and surrounding context of melodies (Dowling & Harwood, 1986). Thus we can investigate how perceptual learning with musical stimuli is related to the development of skills such as those involved in the focusing of expectancy and attention in the pitch and time domain.

Expectancy and Attention

In exploring cognitive development with musical materials, we wish to distinguish clearly among three theoretical constructs that are often confused and to provide them with distinct operational definitions. We will define the processes concerned with the direction of auditory expectancies and contrast those processes with those concerned with the control of attention and with more general processes of perceptual learning. Because these concepts are defined in terms of the task we used in this study, let us now describe it. We used a hidden melodies task (Dowling, Lung, & Herrbold, 1987) in which we could vary features of both target melodies and backgrounds. In this task the listener must identify a target melody whose notes are temporally interleaved with distractor notes. The task increases in difficulty as the interleaved distractor notes are made more similar to the notes of the target in timbre and pitch. Figure 1 illustrates the three levels of difficulty we used.

Panel A depicts what we call the "salient" condition. There the target (the first eight beats of "Twinkle, Twinkle, Little Star") appears in open symbols, denoting a salient timbre contrasting with the timbre of the distractors (filled symbols). Here the distractors differ from the target in timbre, loudness, and pitch, occupying separate pitch ranges above and below the range of the target. This condition closely resembles a melody identification task without distractors, and the target is quite easy for adults to identify. In panel B the task has been made more difficult by introducing distractors of the same timbre as the target (now shown in filled symbols). The listener can pick out the target by focusing attention within its pitch range, because the distractors remain in separate ranges. We called this condition "hidden/out" to denote sameness of timbre with

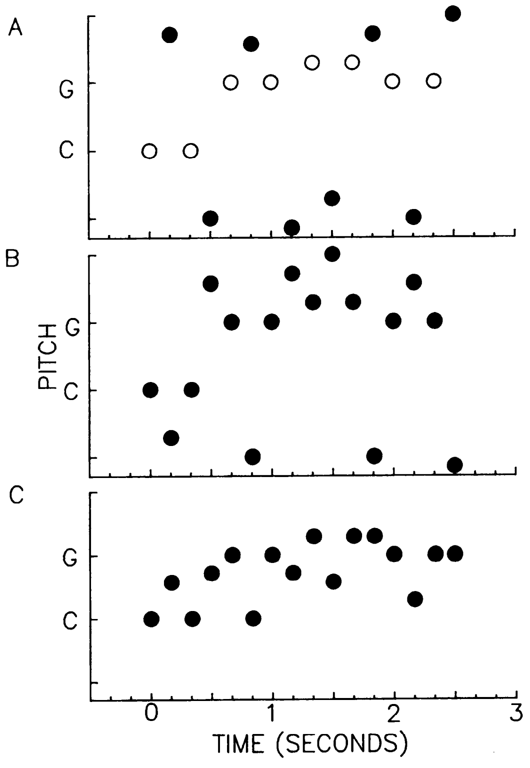

Fig. 1. Three conditions under which targets were presented in successive blocks of the experiment: (A) salient timbre target (open circles, "Twinkle, Twinkle") with distractor notes (filled circles) outside of target range; (B) hidden timbre target (filled circles) with distractor notes outside of target pitch range ("hidden/out"); (C) hidden timbre target with distractors within target pitch range ("hidden/in").

distractors *outside* the target pitch range. The listener can succeed in identifying the target by focusing attention within the appropriate pitch range. We called the third and most difficult condition "hidden/in" (panel C). There same-timbre distractors fell within the same pitch range as the target. In this case the listener's expectancies must be rhythmically paced to select the interleaved target elements. Dowling et al. (1987) suggested that when the listener succeeds at this task "it is as though the listener had a series of 'expectancy windows' aimed more or less accurately in pitch and time, through which expected events—target notes—could be clearly perceived" (p. 643).

We are now ready to define expectancy and attention. By "attention" we refer to processes by which the listener selects a stimulus "stream" or "channel" on the basis of stimulus features such as pitch, loudness, timbre, and direction to source. Stimuli occurring in that channel are processed, novel patterns can be stored in memory, and familiar patterns are usually recognized. The stimulus pattern naturally and automatically reminds the listener of the memory pattern, without the listener needing to be informed of what pattern to expect. In stimuli such as depicted in Figure 1A, attending to the target melody is easy because several salient stimulus features define its channel: timbre, loudness, and pitch. Attending to the hidden/out pattern in Figure 1B is more difficult because only pitch range differentiates targets from distractors. We introduced this hidden/out condition to test listeners' abilities to focus attention on the pitch range of the target and pick up the pattern occurring in that range. Clearly various degrees of success are possible, and complete success would consist of the listener's identification of whatever target patterns occurred in the attended pitch range, even distorted versions of the familiar targets.

Like attention, expectancies can be directed to regions of the stimulus domain defined by stimulus features. Listeners can be led to expect a sound of a given pitch, loudness, or timbre, or coming from a particular location. Unlike attention, however, the focusing of expectancies generally does not lead to the recognition or identification of whatever stimulus patterns occur in the region concerned. The listener can say whether the expected target occurred, but in its absence usually cannot say what did occur instead. This is the case with adults performing the hidden/in condition (Figure 1C) when the set of possible alternative melodies is much greater than two (Dowling, 1973). Unless the listener is cued as to which melody to listen for, the interleaved target is not identified. When the listener knows what melody to listen for, and has a memory representation of that melody, then identification occurs when the target melody is actually present. These then are the components of our definition of the processes of expectancy. "Expectancy" operates when the listener is cued concerning a small set of possible targets and has memory representations of those targets. Expectancy is the process by which the listener succeeds in selecting potential target elements and evaluating them against memory representations. We introduced the hidden/in condition (Figure 1C) as a test of the listener's ability to focus expectancies in terms of the rhythmic pattern of the stimulus sequence, selecting alternate notes for evaluation as target elements.

Clearly it is often the case that attention and expectancy operate together. We typically focus attention on areas of the stimulus domain where targets are likely to appear and generate expectancies concerning those targets. However, when attention operates along with expectancy, we usually succeed in picking up whatever stimulus occurs in the attended region, even if unexpected. It is when attention cannot operate with expectancy that we have the case of expected targets being identified but unexpected ones not. This is what differentiates the hidden/out (attentional focus) and hidden/in (expectancy focus) conditions.

Perceptual Learning

The development of musical cognition involves not only the development of specific skills such as those concerned with the rhythmic control of expectancy and attention just described, but also more general skills developed through perceptual learning with musical materials. Melodies consist of patterns of pitches that can be reproduced at a variety of pitch levels ("transposed" in musical terms) and still remain intact. Dowling (1978) suggested that melodic contour and the musical scale are two important components in memory for the pitch patterns of melodies. We have good reason to believe that those components operate differently with children of different ages (Dowling, 1982; Dowling & Harwood, 1986).

Melodic contour—the pattern of ups and downs of pitch—is an important feature of melodies both for children and adults. For children, who have not yet learned the musical scale invariants of their culture, contour is especially important. From infancy children display a sensitivity to changes in melodic contour (Chang & Trehub, 1977; Trehub, Thorpe, & Morrongiello, 1987), and when they begin to sing spontaneous songs it is melodic and rhythmic contours that they control (Davidson, McKernon, & Gardner, 1981; Dowling, 1984). Contour is still the dominant melodic feature around the age of 6. Children 4 to 6 years old rely on melodic contour information in discriminating novel six-note melodies (Morrongiello, Trehub, Thorpe, & Capodilupo, 1985). By the age of 6, however, children have begun to take exact pitch interval information and conformity to a tonal scheme into account in the case of familiar melodies

(Dowling, 1987; Trehub, Morrongiello, & Thorpe, 1985; Trehub, Cohen, Thorpe, & Morrongiello, 1986).

Adults rely on both contour and intervals conforming to the tonal scheme in melody recognition. With adults as with children, melodic contour is more important in the recognition of novel melodies, whereas pitch intervals are more important with familiar melodies accessed in long-term memory (Dowling & Fujitani, 1971; Bartlett & Dowling, 1980; Dowling & Bartlett, 1981; Trehub et al., 1985; DeWitt & Crowder, 1986). However, throughout childhood and into adulthood the tonal scheme has greater and greater impact on judgment of musical stimuli (Krumhansl & Keil, 1982) and melody recognition (Imberty, 1969; Zenatti, 1969, 1975). Dowling (1982) summarized the developmental sequence as "one of going from the baby's ability to distinguish gross features such as contour and pitch level, to the 5-year-old's grasp of tonal scales and ability to discriminate key changes, to the adult's ability to detect small changes of interval size" (p. 415), concluding that "the development of melody-processing skills can be seen as a progression from the use of gross, obvious features to the use of more and more subtle features" (p. 421).

In order to explore the impact of these changes in the use of contour and tonality in the development of music processing skills on performance in the hidden melodies task, we introduced three types of contour-preserving targets and two relationships of tonality between target and distractor notes. The three target types were selected to determine the role of melodic contour, pitch intervals, and tonal scale. We wanted to determine whether children could follow a familiar target melody even if it wandered in pitch from its familiar form; that is, if it preserved the contour but not the pitch intervals of the familiar original. Thus, in addition to the "straight" versions of the familiar targets, we included "wandering" targets that altered some of the melody's intervals while preserving their direction. The three types of target are illustrated in Figure 2. There the straight version of "Twinkle, Twinkle" is shown in open circles. When a target wandered it either stayed within the key of the original (in which case we call it a "tonal" wandering target—triangles), or it moved into a distant key (in which case we call it an "atonal" wandering target—diamonds). We were curious to see at what ages staying within the expected key would have an effect, compared with departing from it.

Because the tonality of the wandering targets varied, and we thought it likely that target tonality would interact with distractor tonality especially with hidden targets, we thought it best to vary the tonality relationship between targets and distractors. Therefore in separate conditions we used what we are calling "tonal" distractors (in the key of the original melodies) and "atonal" distractors (drawn from a distant key). This produced four combinations of wandering target tonality and distractor to-

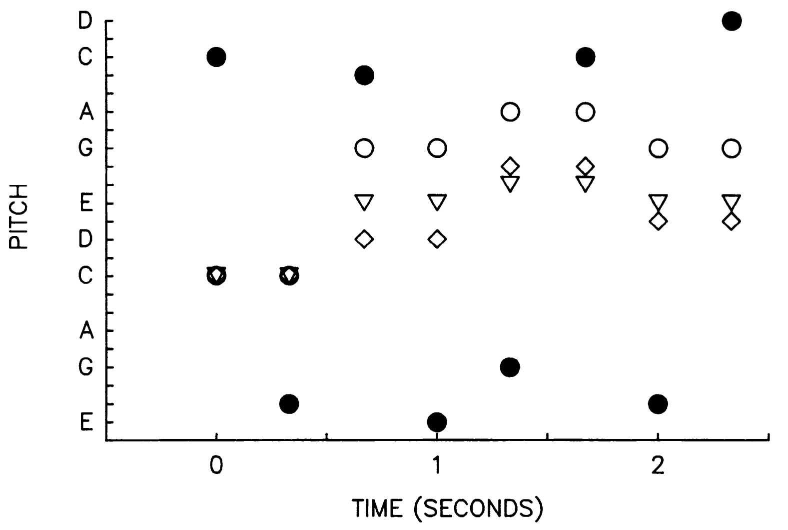

Fig. 2. "Straight" version of "Twinkle, Twinkle," in salient condition (open circles); Tonal Wandering version of "Twinkle, Twinkle" (open triangles); Atonal Wandering version of "Twinkle, Twinkle" (open diamonds). Distractors are denoted by filled circles.

nality: tonal/tonal in which target and distractor were in literally the same key (C major); tonal/atonal and atonal/tonal, in which target and distractor keys were in distant keys; and atonal/atonal in which their keys were similar (and distant from the key of the tonal targets).

There are four questions that the inclusion of the two types of wandering targets and distractors of similar or contrasting tonality permits us to ask. (1) When targets are presented in a salient timbre, this task resembles a melody identification task without distractors. With salient targets, we can assess the importance of melodic contour and of tonality in melody recognition. We could imagine that 5- and 6-year-olds might find same-contour wandering targets relatively easy to identify and that they might remain relatively unaffected by target tonality. Older children, in contrast, might be more sensitive to the straight/wandering difference in stimuli, and to differences of tonality. (2) The hidden/out condition allows us to test children's ability to aim attention in pitch. Improvements with age in the identification of hidden wandering targets is an index of the extent to which listeners succeed in aiming attention in pitch and picking up whatever stimulus pattern occurs in the attended pitch region. (3) When targets are hidden among distractor notes of the same pitch and timbre, then the fact that a target wanders from its expected pitches should make it especially difficult to discern, on the supposition that the listener achieves identification by aiming expectancies in time. Unlike the case with attention, we suppose that listeners will not be able easily to identify whatever stimuli occur in the expected regions. (4) To the extent that listeners are sensitive to invariants of tonality, then similarity and contrast of target and distractor tonality should affect performance in the hidden-melodies conditions. We could imagine that such effects would emerge with older children and adults, for whom converging evidence suggest a greater sensitivity to dimensions of tonality.

Design

The above considerations led us to a fairly elaborate design, which we will outline here before describing it in detail. We used two between-group variables: Age/Experience (children 5–6, 7–8, and 9–10 years old, and musically experienced and inexperienced adults) and Distractor Tonality ("tonal" vs. "atonal" distractors). For a given group of subjects the entire experiment made use of either distractors in the same key as the straight targets, or in a distant key.

There were two within-group variables: three target salience levels (salient, hidden/out, hidden/in—see Figure 1), and three target types (straight, tonal wandering, atonal wandering—see Figure 2). Salient targets had a different timbre and lay in a separate pitch range from distractors. Hidden/out targets and their distractors had the same timbre but were still in separate pitch ranges. Hidden/in targets also had distractors of the same timbre, but the distractors lay in the same pitch range as the target. Straight targets replicated the familiar version of the tune, always in the key of C major. Wandering targets preserved the contour but not the intervals of the tune, either staying within the original key ("tonal") or departing from it ("atonal").

Method

The design included two between-groups variables: Age/Experience (three age ranges of 5–6, 7–8, and 9–10 years, plus two adult experience levels) and Distractor Tonality (tonal vs. atonal). Different groups also received one of the two different randomizations of the order of stimuli. There was a 3×3 array of within-group comparisons: Target Salience (salient, hidden/out, hidden/in) and Target Type (straight, tonal wandering, atonal wandering).

SUBJECTS

One-hundred fifty-eight children between 5 and 10 years of age served as subjects, with between 48 and 57 children in each of the three age groups. Between 9 and 18 children were in each Age × Distractor Tonality × Order cell of the design. The subjects were recruited with parental consent from local daycare centers and schools. Fifty-three adult undergraduates at the University of Texas at Dallas (mean age 29.50 years) also served. Twenty-four of the adults had 2 years or more of explicit musical training (mean of 7.17

years) and were categorized as musically experienced. The remaining 29 adults were categorized as musically inexperienced.

STIMULI

Target stimuli based on the familiar tunes "Old MacDonald Had A Farm" and "Twinkle, Twinkle Little Star" were produced by a Commodore 64 computer by using its 6581 sound interface device. The stimuli were recorded on tape and presented to subjects via loudspeaker in 16-note melodies at a rate of 6 notes per second. Distractor notes were temporally interleaved among the notes of the target melodies, so test stimuli alternated between target notes and distractors. Therefore, a note usually sustained in the familiar version of the targets (e.g., the last note of a phrase) was split into repeated notes to accommodate the interleaved notes.

The stimuli were arranged in 30 trials consisting of three blocks of successively more difficult levels of target salience: salient, hidden/out, and hidden/in (see Figure 1). Each block included three target types: tonal straight, tonal wandering, and atonal wandering (see Figure 2). Tonal straight targets repeated the melody in its familiar form in the key of C major, beginning on middle C (fundamental frequency = 262 Hz). Tonal and atonal wandering target stimuli were generated by beginning on middle C and by altering the size of three-quarters of the intervals by between one and five semitones each, while preserving the contour (ups and downs) of the original target. Tonal wandering targets stayed within the key of the original; atonal ones did not. Patterns of repeated notes in the original remained unchanged in wandering targets. The mean change in altered intervals in the wandering stimuli was 1.31 semitones.

In the first block of trials, targets were presented in a salient (square-wave) timbre interleaved with a softer (triangle-wave) background of distractors lying in separate pitch ranges above and below the pitch range of the target. In the six trials of the first block, each of the three target types appeared twice, once with each melody. The second and third blocks of "hidden" trials consisted of 12 trials each, in which targets had the same timbre and loudness as the distractors. The second block presented hidden/out targets with distractors in separate pitch ranges as in block 1. In the third hidden/in block, distractors lay in the same pitch range as the target. In blocks 2 and 3, each of the three stimulus types was presented four times and each melody occurred twice for each stimulus type.

Distractors outside the pitch range of the target notes (blocks 1 and 2) consisted of two random permutations of eight notes occupying a pair of ranges straddling that pitch range (from B in the second octave below middle C up to the A below middle C, and from the F above middle C to the E in the second octave above middle C). Distractors generally in the same pitch range as the target consisted of two random permutations of eight pitches in the range from E below middle C to the A above middle C.

The variable of distractor tonality depended on the key relationship of distractors to straight targets. Tonal distractors were in the same key as straight targets (C major), and atonal distractors were from a distant key (F♯ major) consisting mainly of semitones falling in between the scale pitches of tonal targets. Tonal distractors outside the pitch range of the target notes consisted of sets of consecutive scale notes straddling the target's pitch range—three above and three below. Tonal distractors within the pitch range of the target consisted of six consecutive scale notes in the middle of the target's pitch range. Atonal distractors outside the pitch range of the targets consisted of sets of three consecutive pitches from the key of F♯ major, omitting E♯ (=F). Atonal distractors within the pitch range of the target were similarly chosen and fell within five semitones of the middle of the target's pitch range.

PROCEDURE

Subjects served in small group sessions. Subjects were told to listen to the brief melodies and decide if each melody sounded like "Old MacDonald Had A Farm" or "Twinkle,

Twinkle Little Star." The subjects were instructed to respond on each trial by circling the "O" for "Old MacDonald or the "T" for "Twinkle, Twinkle" on the answer sheet. The experimenter explained that the melodies had identical rhythms, that other notes were going on in the background, that some notes were changed to sound like they were played on the black keys on the piano, and sometimes the notes were changed to wander up and down. The subjects listened to a sample of each melody. After the first block of six trials, subjects were informed that whereas before target melodies had a different sound from the background, now targets and background would have the same sound. After the second block subjects were told that distractors would now move within the pitch range of the targets, so the task would be somewhat harder.

Results

We initially subjected the data, in the form of percent correct for all the subjects, to a four-way analysis of variance (ANOVA): 5 Age-or-Experience Levels × 2 Distractor Tonalities (tonal vs. atonal) × 3 Target Salience Levels (salient, hidden/out, hidden/in) × 3 Target Types (straight, tonal wandering, atonal wandering). To further clarify the effects, and to ensure that observed effects of age held across the age-range of children tested and were not simply due to including adults along with children in the analysis, we ran additional ANOVAs on adults and children separately.

ALL AGES

The ANOVA across all age and experience levels found significant main effects of Age/Experience [F (4, 201) = 52.51, p < .0001], Target Salience [F (2, 402) = 39.79, p < .0001], and Target Type [F (2, 402) = 23.48, p < .0001]. Those effects are shown in Figure 3. Performance improved with age and experience, performance declined as targets became more hidden among distractors, and straight targets were easier to recognize than either form of wandering target.

The Distractor Tonality × Target Salience interaction was significant [F (2, 402) = 4.59, p < .02] (Figure 4). Salient targets were easier to recognize with tonal interference, whereas hidden targets were easier with atonal interference. That this effect was qualified by the relationship of target tonality to distractor tonality is shown in the significant interaction of Distractor Tonality × Target Salience × Target Type [F (4, 804) = 3.01, p < .02] (Figure 5). As in Figure 4, hidden/in targets were uniformly easier with atonal distractors. However, salient targets were easier with tonal interference only for tonal (straight as well as wandering) targets. Atonal salient (wandering) targets were easier with atonal distractors. Similar-tonality distractors facilitated identification of otherwise salient targets—a "tonality consonance" effect. At the intermediate level of target

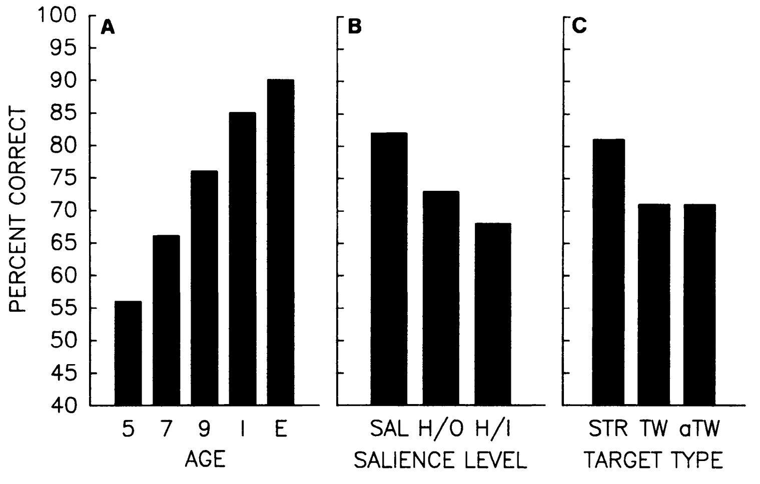

Fig. 3. Main effects in the overall ANOVA, expressed in percentage of correct responses: (A) Effect of age and experience for groups of age 5–6, 7–8, and 9–10 years and inexperienced (I) and experienced (E) adults; (B) Effect of target salience for salient (SAL), hidden/out (H/O), and hidden/in (H/I) targets; (C) Effect of target type for straight (STR), tonal wandering (TW), and atonal wandering (aTW) targets.

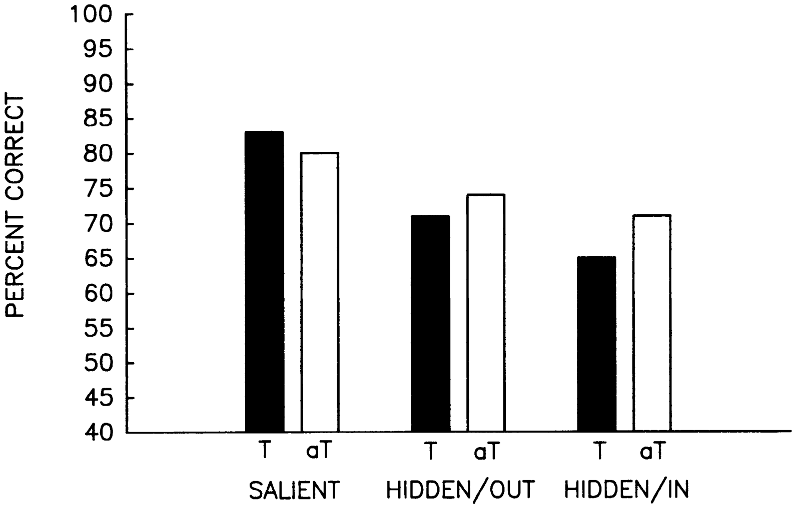

Fig. 4. Interaction of target salience and distractor tonality. T = tonal, aT = atonal.

obscurity with hidden/out targets, that interaction of target vs. background tonality was reversed, with tonal targets easier with atonal distractors and atonal targets easier with tonal distractors—a "tonality contrast" effect. Identification of the most difficult hidden/in targets was generally facilitated by atonal distractors, suggesting a tonality-contrast

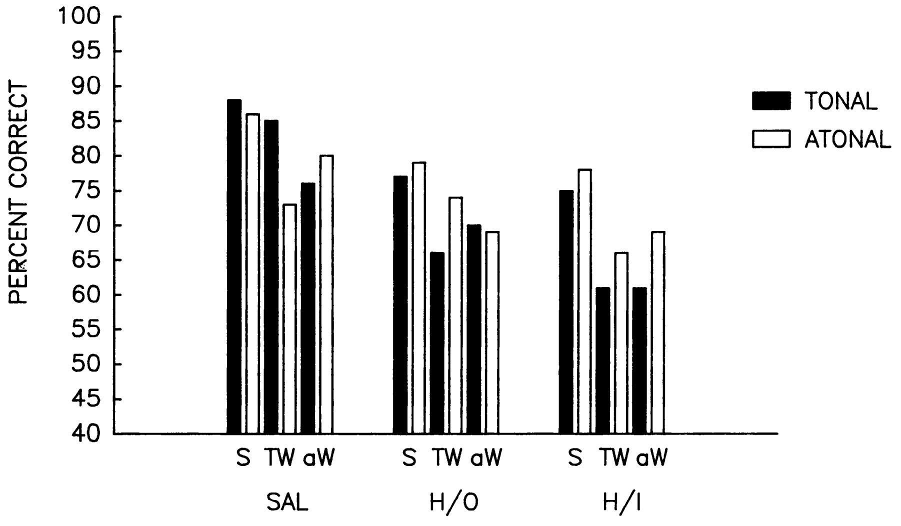

Fig. 5. Interaction of target salience, target type, and distractor tonality. Filled bars refer to tonal distractors; open bars to atonal. S = straight, TW = tonal wandering, aW = atonal wandering, SAL = salient, H/O = hidden/out, H/I = hidden/in.

effect in which subjects attempted to hear all targets in the familiar key.

Finally, there was a significant interaction of Age × Distractor Tonality × Target Salience [F (8, 402) = 2.53, $p < .02$] (Figure 6). If we follow the relationship of tonal vs. atonal distractors across age for each of the three degrees of target salience, we find that the relationship shown in Figure 4 generally holds at all ages except the youngest. It is clear also that, for experienced adults, background tonality is an important factor for salient targets and not at all for hidden/in targets.

CHILDREN

All the main effects and interactions in the overall ANOVA were significant in the ANOVA for the children alone: Age [F (2, 152) = 35.36, $p < .0001$], Target Salience [F (2, 304) = 35.30, $p < .0001$], Target Type [F (2, 304) = 19.97, $p < .0001$], Distractor Tonality × Target Salience [F (2, 304) = 3.49, $p < .05$], Age × Distractor Tonality × Target Salience [F (4, 304) = 3.58, $p < .01$], and Distractor Tonality × Target Salience × Target Type [F (4, 608) = 2.95, $p < .02$].

The only additiional significant interaction in the ANOVA for the children's data was that of Age × Target Salience × Target Type [F (8, 608) = 2.14, $p < .05$]. Comparison of panels A and B in Figure 7 shows that the pattern for different target types across age was very different for salient vs. hidden trials. The hidden conditions (Figure 7B) produced the

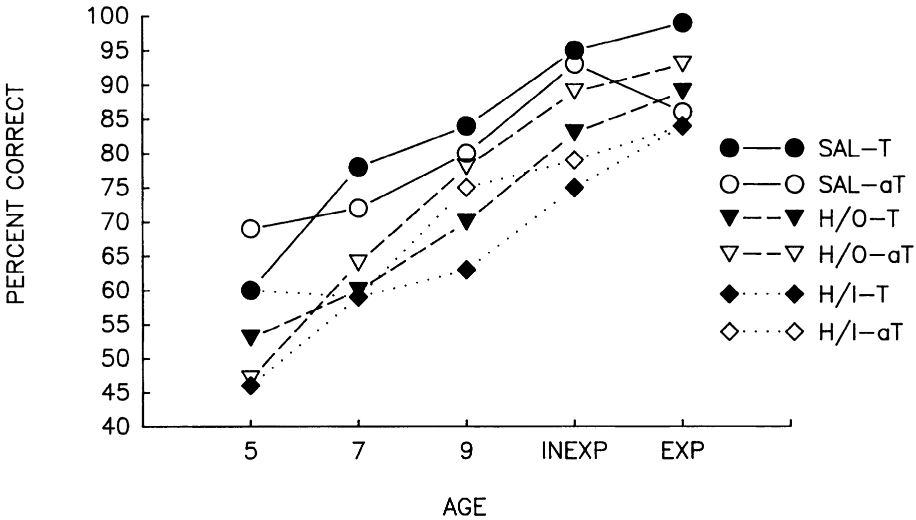

Fig. 6. Interaction of age with target salience and distractor tonality. SAL = salient, T = tonal, aT = atonal, H/O = hidden/out, H/I = hidden/in.

simpler pattern of results in which the main effects of Figure 3 can be seen for all but the youngest age group. That is, there was little difference between tonal and atonal wandering targets in a given condition, but the hidden/out condition was easier than the hidden/in, and straight targets were easier than either type of wandering target. (The adult data are included in the figure for comparison.)

It is with salient targets (Figure 7A) that we find the interesting part of this interaction. There 5- and 6-year-olds found wandering targets as easy to identify as straight targets. By the age of 7 and 8 years performance improved, but only for the *tonal* straight and wandering targets; at that age children found it relatively difficult to follow an *atonal* wandering target. By 9 and 10 years of age, performance had begun to improve on atonal wandering targets, but at that age children found both tonal and atonal *wandering* targets relatively difficult, while displaying a virtually adult level of performance with straight targets.

ADULTS

Only three of the significant effects of the overall ANOVA appeared in the ANOVA for adults: Target Salience [F (2, 98) = 16.38, $p < .0001$], Target Type [F (2, 98) = 14.94, $p < .0001$], and the interaction of Distractor Tonality × Target Salience [F (2, 98) = 4.04, $p < .05$]. In addition, the ANOVA for the adults disclosed an interaction of Experience × Distractor Tonality × Target Salience × Target Type [F (4, 196) =

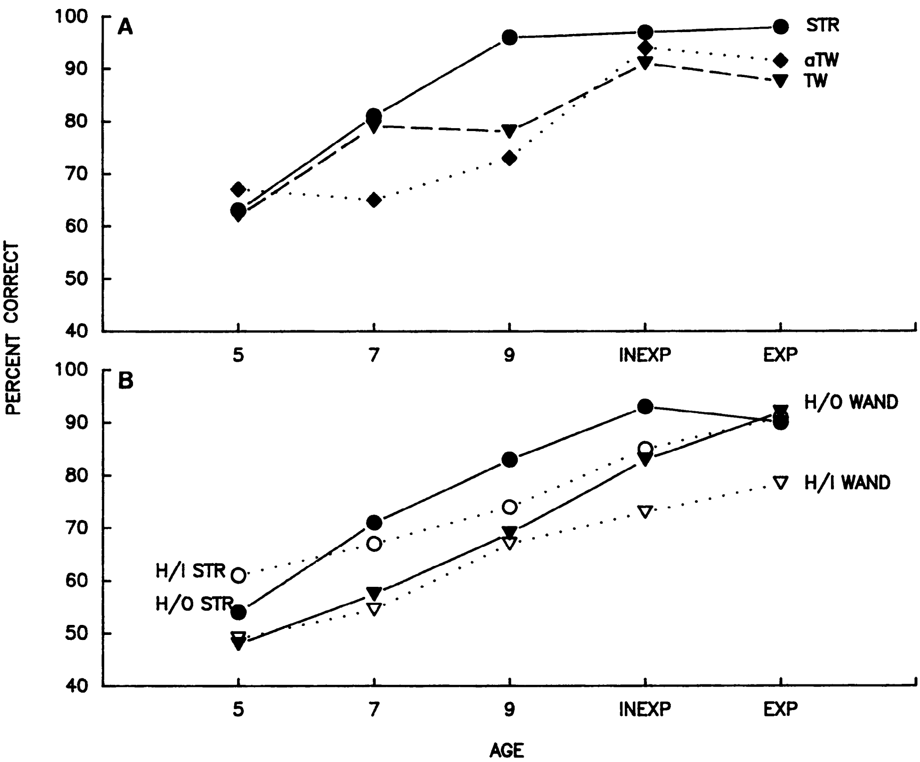

Fig. 7. Interaction of age with target salience and target type. The results for salient targets are shown in panel A (STR = straight, aTW = atonal wandering, TW = tonal wandering). The results for hidden targets are in panel B (H/I = hidden/in, H/O = hidden/out, STR = straight, WAND = wandering). Because in the latter case tonality of wandering target had almost no effect on the data, the data are collapsed across those two types of wandering target for clarity.

2.79, $p < .05$], in which experience modulated the interaction shown in Figure 5. This interaction is shown in the two panels of Figure 8. Inexperienced adults (panel A) displayed the "tonality consonance" pattern of Figure 5 for salient targets; their pattern was similar to that of Figure 5 for hidden/out targets, tending in the direction of a tonality contrast effect, and they showed a clear tonality contrast effect with hidden/in targets (unlike Figure 5). Experienced adults (panel B), in contrast, performed generally worse with atonal distractors and salient targets; they showed a tonality contrast effect with hidden/out targets (like Figure 5) and a tonality consonance effect with hidden/in targets (unlike Figure 5 or Figure 8A).

We should note that the data points bearing on developmental trends (as in Figures 6 and 7) are in general based on homogeneous distributions. That is, moderate levels of apparent success are not the result of a few

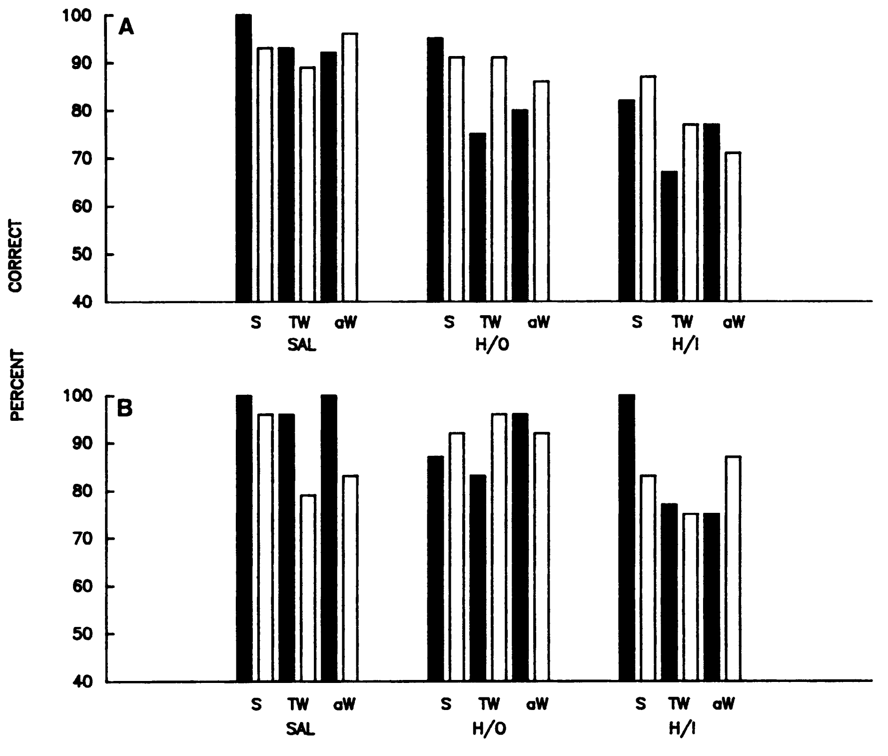

Fig. 8. Interaction of target salience, target type, and distractor tonality with experience for the adult subjects. Filled bars refer to tonal distractors; open bars to atonal. Panel A shows results from inexperienced subjects, and panel B from experienced. S = straight, TW = tonal wandering, aW = atonal wandering, SAL = salient, H/O = hidden/out, H/I = hidden/in.

children solving the task with perfect performance and the rest performing at chance. This observation is limited by the rather coarse grain of the data. That is, with salient targets there were only two data points per child per target type, so that this question could not be addressed adequately in that case. In the hidden/out and hidden/in conditions, however, there were four trials per target type and the question could be addressed. In no case was the proportion of children scoring 75% correct less than the proportion scoring both 50% and 100%. That is, in no case did the distribution of scores appear bimodal.

Discussion

It is not surprising that performance improves with age and target salience, and that wandering targets are harder to identify than straight targets (as shown in Figure 3). More interesting aspects of the data from the point of view of cognitive development are found in the pattern of improvement with age in terms of salience, target type, and tonality of target and background. These qualitative differences in the course of development indicate time periods during which the various component skills come into use. The two principal areas in which we see such patterns emerge are (1) changes in the ability to focus attention to pitch and (2) changes in the importance of different melodic features in melody identification. The third aspect of the results that warrants discussion concerns the effects of similarity and contrast in the tonality relationships of targets and distractors in the various conditions of the experiment.

FOCUSING ATTENTION IN PITCH AND EXPECTANCY IN TIME

The child has some difficulty focusing attention in pitch at the age of 5 or 6 years and shows clear evidence of that ability by age 9–10 years. This can be seen in the top two curves in Figure 7B, which denote performance with straight versions of targets in the hidden/out and hidden/in conditions. Starting from not much above chance at age 5–6 years, performance improves with age. The increase was steeper for the hidden/out condition, and by 10 years old the children were distinctly better at the hidden/out than the hidden/in condition, clearly displaying the ability to focus attention within the pitch range bracketed by the hidden/out distractors.

The more stringent test of the listener's ability to focus attention in pitch and pick up whatever occurs in the attended pitch range is provided by wandering targets in the hidden/out condition (filled triangles in Figure 7B). There we find that not until after age 10 does performance rise much above chance and diverge from performance with hidden/in wandering targets. And it is only experienced adults who found hidden/out wandering targets as easy as straight ones.

We can take performance with straight targets in the hidden/in condition (open circles in Figure 7B) as an index of success in aiming expectancies in time. Performance at the earliest ages was slightly above chance and almost as good as with salient targets, suggesting that by age 5–6 years at least some children have some success with this task. By age 9–10 performance was clearly better than chance, and experienced adults found the straight hidden/in targets as easy as the straight hidden/out.

Performance with wandering targets in the hidden/in condition (open triangles in Figure 7B) remained distinctly poorer than in any of the other conditions even into adulthood. This suggests that even experienced adults found it very difficult to focus *attention* rhythmically at these presentation rates to pick up whatever stimuli occurred in the critical time slots. Both children and adults found it possible, however, to focus *expectancies* in time, as indicated by performance with straight hidden/in targets.

We have no doubt that attention naturally waxes and wanes over time. Acquiring rhythmic control over the focusing of expectancies and attention—bringing them into synchrony with important rhythms in the environment—is necessary for the pickup of critical information in event sequences like those of speech and music that are spread out in time (Jones, 1981). However, the presentation rates used in this study were more suited to the control of expectancies in time, as contrasted with attention. The development of the rhythmic control of attention clearly merits further study.

MELODIC FEATURES

Turning away from consideration of attention and expectancy, we can see in Figure 7A changes with age in the identification of the three types of salient target. This task is very much like a melody identification task without distractors. Adults found this version of the task somewhat easier than the no-distractor version of Dowling and Fujitani (1971, Expt. 2).

For the youngest children, performance identifying salient targets was low overall, but equally good with all three target types. At those ages, it did not seem to matter whether the target wandered in pitch from its familiar form, nor whether that wandering took it into more distant regions of tonality. This result is consistent with the notion that at the age of 5–6 years the dominant feature of the child's representation of a melody is contour, and that tonality has not yet emerged as a defining feature of melodies.

This pattern of results changed by age 7–8 years. Between 5–6 and 7–8 years there was no improvement in performance with atonal wandering targets. There was, however, a marked improvement with tonal straight and wandering targets, which showed equal increases in percent correct. This indicates that by the age of 7–8 years tonality has become an important feature of melodies, in addition to contour. Wandering tonal melodies were as easily identified as straight tonal melodies—what was important was their coherent tonality and their contour.

By the age of 9–10 years, performance with straight targets again improved and was clearly differentiated from performance with both tonal and atonal wandering targets. Now precision of pitch intervals emerges as an important feature of melodic representations. Contour is still in use—performance with atonal wandering targets has improved by this age—but what contributes most to effective melody identification is the conformity of a target to the exact interval pattern of the familiar melody.

Finally, by adulthood listeners were flexible enough to use a variety of melodic features effectively in recognizing both straight and wandering salient targets with a high degree of accuracy. We can see in the progression shown in Figure 7A both the shifts in strategy arising from children's dependence on this or that characteristic melodic feature at different ages (contour-tonality-intervals) and the flexibility of adult competence in using a variety of features effectively when appropriate.

TONALITY

The simplest effect of tonality can be seen in Figure 4: the predominantly tonal targets were best discerned with tonal distractors when presented in salient timbre and, when hidden, with atonal distractors. In other words, when the target was easy to identify because of its contrast in timbre with the background, then distractors that did not conflict with its key facilitated identification. However, when the target was hard to identify because of timbral similarity to distractors in the hidden conditions, then contrast of tonality became important. Note that this tonality contrast effect was stronger with hidden/in targets, where in this account tonality contrast was most needed. This result converges with that obtained by West, Cross, and Howell (in press) in a melodic recognition task in which targets were presented in two-part counterpoint. When the target was in the upper, more salient, voice, then performance was better when the upper and lower voices were in the same key. But when the target was in the lower, more hidden, voice, performance was better when the two voices were in different keys.

The effects of tonality "consonance" and contrast in relation to experience emerged most clearly with the adult listeners (Figure 8). Inexperienced adults showed the contrast effect with hidden targets just described, whereas more experienced adults—better able to use rhythmic focusing of attention to discern the hidden targets—exhibited a tonality "consonance" effect. That is, tonality contrast was only jarring when the listener could discern the target without its aid.

Qualitative changes in the importance of tonality with development can be seen in relative levels of performance. It is clear from Figure 6 that from a somewhat chaotic pattern for the 5- to 6-year-olds the coherent pattern of Figure 4 emerged from age 7 years on: salient targets were best identified with atonal distractors and hidden targets, with tonal distractors. Thus the tonal scheme began to have an impact on performance around the age of 7 years, in agreement with the converging evidence cited in the introduction.

In summary, then, apart from the obvious effects of age, salience, and straight vs. wandering targets shown in Figure 3, the principal implications of this study concern patterns of cognitive development in three areas: the development of the ability to focus attention in pitch, the shift in importance of melodic features with age, and the shift in the function of tonality contrast and similarity with age and experience. As children grow older, they become able to control attention by focusing it on specific pitch regions where target events are likely to occur. They also shift from reliance on broad features such as melodic contour to subtler features such as tonality and precise interval size. And as children grow older they develop a more precise sense of tonality (as described by Krumhansl & Keil, 1982), and they use that sense of tonality in their perceptual strategies for separating targets from distractor notes when tonality differences and similarities are in play. Approaching the end of that developmental sequence, we saw that musically experienced adults failed to experience the tonality contrast effect with hidden/in targets that was characteristic of all the other groups. At that level of experience (a mean of 7 years of music lessons), and with perceptual learning during the experiment, they were able to discern the thoroughly hidden targets very well without tonality contrast. In that case, tonality contrast was disruptive rather than helpful.

In this study we used rather simple materials ("Old MacDonald" and "Twinkle, Twinkle") in an elaborate statistical design. The simple materials made our task accessible to the youngest children, but yet were complex enough so that only in the easiest conditions did adult performance brush the ceiling. The elaborate design was intended to represent aspects of real-world stimuli, such as tonality relationships, that we thought could not reasonably be ignored. It is clear from this discussion, however, that their inclusion has raised as many questions as it has answered. Two principal questions that occur to us are (1) Would the present results concerning wandering melodies generalize to a wide range of melody contours and rhythms? And (2) might listeners have been led to different strategies in dealing with tonality similarity and contrast if all four possibilities of tonal and atonal targets and distractors had been mixed within a block of trials?[1]

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