Infants' Perception of Melodies: Changes in a Single Tone*

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Infants 6 to 8 months of age were exposed to repetitions of a 6-tone sequence or melody, then tested for their detection of six transformations of that sequence, each of which incorporated a frequency change in one of the six positions. In Experiment 1, infants showed evidence of discriminating all changes. Moreover, they performed significantly better on changes that extended the frequency range of the original melody. When the task was made more difficult in Experiment 2, performance deteriorated but frequency changes in all positions were still detectable.

It has been established that infants can detect changes in the component frequencies and frequency relations of a multitone sequence or melody (Chang & Trehub, 1977a, b; Demany, 1982; Kinney & Kagan, 1976; McCall & Melson, 1970; Trehub, Bull, & Thorpe, 1984). Trehub et al. (1984) suggest that, in listening to a melody, infants encode global information about the melodic contour or direction of successive frequency changes. They encode such global information as opposed to specific information about the absolute frequencies of individual tones or the frequency ratios between adjacent tones. In addition, Trehub et al. (1984) suggest that infants also encode information about the overall frequency range of a melody. Thus, infants respond to new melodies as familiar, if these melodies have the same contour and approximate frequency range as previously heard melodies and as novel, if there are differences in either contour or range. This global processing strategy is similar to that used by adults with melodies heard for the first time (Dowling, 1978, 1982; Dowling & Fujitani, 1971).

The hypothesis that infants encode contour and range, although consistent with available evidence on infant melody discrimination, generates some predictions that have not been tested to date. For example, if contour and range are the only relevant parameters, then changes in even a single component tone

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of a melody should be discriminable by infants, if these changes result in an alteration of melodic contour or frequency range. Since all previous studies have incorporated changes in several, if not all, tones, it is possible that such redundant cues could facilitate or perhaps underlie the discrimination observed.

Research with adults has indicated that they can simultaneously hold in memory 4 to 7 tones of an unfamiliar melody (Berg, cited in Williams, 1981; Pollock, 1952) and that their retention of the initial and final tones is superior to the middle tones (Frances, cited in Bentley, 1966; Ortmann, 1926; Williams, 1975). Bentley (1966) contends, however, that for children and adults, the final note is easiest to remember and the initial note, most difficult. Perhaps differences in tonal configuration, sequence length, and magnitude of pitch change contributed to these disparities. It has also been found that melodies are remembered best when they conform to accepted music conventions such as tonality (Day, 1981; Long, 1977). When adults have been required to make same/different judgments of melodies with a single note changed by one or two semitones, performance is superior for 7-note compared to 9-note melodies, for “melodic” compared to “unmelodic” melodies, and for musically experienced compared to inexperienced listeners (Day, 1981).

Zenatti (1969) investigated children's perception of 3-note melodies with a single note changed. Children 5 years of age could not accomplish the task of identifying the changed note, but by 8, they became more proficient, particularly with tonal melodies. Bentley (1966) used a similar task with 5-note melodies for children 7 to 14 years of age. The younger children performed poorly but an increase in accuracy of roughly 8% per year was observed, with performance of the 14-year-olds being approximately equivalent to that of adults. It is quite likely, however, that the very difficult task of identifying the position of the changed note, as opposed to detecting its presence, accounted for the very poor performance observed with young children.

The objective of the present investigation was to determine whether a frequency change in a single component tone of a brief tonal melody is discriminable to infants. Accordingly, we familiarized infants with 6-tone melodies in the key of C major and subsequently evaluated their discrimination of six altered melodies, each of which incorporated a frequency change in one of the six possible positions. The magnitude of change was 10 semitones, except when this resulted in a note outside the key of C major, in which case a 9-semitone change was used. The direction of frequency change (up or down) was selected so as to produce an alteration in melodic contour. In some cases, this resulted in a corresponding change in frequency range; in other cases, it did not. This permitted the evaluation of discrimination on the basis of the single cue of contour violation and on the basis of the joint cues of contour and range.

**EXPERIMENT 1**

**Method**

*Subjects.* The subjects were 33 healthy, full-term infants from 6 to 8 months of age. Infants were excluded from the sample if they failed to meet a
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predetermined training criterion that is described in Procedure (N=3). All infants who met the training criterion subsequently completed the 36-trial testing session. The final sample of 30 infants consisted of 15 males and 15 females, with a mean age of 7 months, 3 days. Each infant was tested with one of the three standard melodies.

**Apparatus and Stimuli.** The experiment was controlled by a microcomputer (Commodore PET, Model 2001), which operated the remaining electronic equipment through a custom-built interface. The stimuli were generated on line by a synthesizer/function generator (Hewlett-Packard 3325A) and presented via one channel of a stereo amplifier (Technics Model SU 7300) over a single loudspeaker (Radio Speakers of Canada, Model C8C). The loudspeaker was positioned above a four-chamber, smoked Plexiglas box that contained four different mechanical toys. Stimulus intensity was controlled by the synthesizer and calibrated with an impulse precision sound level meter (Bruel and Kjaer, Model 2204). Tone onset and offset were controlled through an electronic switch (Med Associates ANL-913). Testing was carried out inside a double-walled, sound-attenuating chamber (Industrial Acoustics Co.) measuring 2.8 × 3.1 m.

Three 6-tone sequences based on those used in earlier research with adults (Massaro, Kallman, & Kelly, 1980) and infants (Trehub et al., 1984) were selected for the current experiment (see Table 1). Transformations of each melody were created by replacing a single tone of the melody with a tone either 10 semitones higher or lower. In the few cases in which a 10-semitone change fell outside the acceptable notes of the key of C major, the tone was changed by only 9 semitones; these exceptions are noted by an asterisk in Table 1. Thus, all of the notes of the transformed melodies remained in the key of the original melody. Such changes were made at each of the six positions of each sequence, making a total of six contrasting patterns for each standard or background melody. The direction of change (higher or lower) was selected so as to alter the contour of the melody. All standard sequences and transformations are shown in musical notation in Fig. 1 and, in terms of their component frequencies, in Table 1.

The component tones of each sequence were sinusoidal waveforms, 200 ms in duration, with rise and fall times of 30 ms and intertone intervals of 200 ms; thus each melody was 2.2 s in duration. The interval between melody presentations was 1500 ms. Stimulus intensity, measured at the approximate location of the infant's head, averaged 68 dB-C; ambient noise level, measured at this location, was approximately 48 dB-C (18dB-A). The melodies were structured with the tonic (the key note, middle C or 262 Hz, in this case) as the initial tone; the final note was always the dominant of C major, which is a phrase ending consistent with standard rules of musical composition.

**Procedure.** During the session, the infant was seated on the parent's lap in one corner of the booth facing the experimenter. To the infant's left, at an angle of 45°, were the loudspeaker and the toy display box. The experimenter
### TABLE 1

Frequencies and Note Names for Stimulus Sequences

<table>
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<tr>
<th>Melody</th>
<th>Frequencies</th>
<th>Musical Notes</th>
<th>Contour</th>
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<td></td>
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<td>Standard</td>
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<td>+ - ++ +</td>
</tr>
<tr>
<td>Training</td>
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<td>A₄⁺, A₄, G₄, B₃, C₅, A₃</td>
<td>- - ++ -</td>
</tr>
<tr>
<td>Position 1</td>
<td>440 440 392 494 262 392</td>
<td>A₄⁺, A₄, G₄, B₃, C₅, G₅</td>
<td>- - ++ -</td>
</tr>
<tr>
<td>Position 2</td>
<td>262 247 392 494 262 392</td>
<td>C₄, B₃, G₃, B₃, C₅, G₅</td>
<td>- - ++ -</td>
</tr>
<tr>
<td>Position 3</td>
<td>262 440 392 494 262 392</td>
<td>C₄, A₄, F₃, B₃, C₅, G₅</td>
<td>++ + - -</td>
</tr>
<tr>
<td>Position 4</td>
<td>262 440 392 294 262 392</td>
<td>C₄, A₄, G₄, D₄⁺, C₅, G₅</td>
<td>- - ++ -</td>
</tr>
<tr>
<td>Position 5</td>
<td>262 440 392 392 262 392</td>
<td>C₄, A₄, G₄, B₃, C₅, A₃</td>
<td>+ - ++ -</td>
</tr>
<tr>
<td>Position 6</td>
<td>262 440 392 494 262 220</td>
<td>C₄, A₄, G₄, B₃, C₅, A₃</td>
<td>- - ++ -</td>
</tr>
<tr>
<td><strong>Sequence 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>262 247 220 330 294 196</td>
<td>C₄, B₃, A₃, E₁, D₁, G₃</td>
<td>- - ++ -</td>
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<tr>
<td>Training</td>
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<td>D₃, B₃, A₃, E, D, F₁</td>
<td>+ - ++ -</td>
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<tr>
<td>Position 1</td>
<td>147 247 220 330 294 196</td>
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<td>+ - ++ -</td>
</tr>
<tr>
<td>Position 2</td>
<td>262 440 392 494 262 392</td>
<td>C₄, A₄, A₃, E₁, D₁, G₃</td>
<td>+ - ++ -</td>
</tr>
<tr>
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<td>C₄, B₃, G₄, E₁, D₁, G₃</td>
<td>- - ++ -</td>
</tr>
<tr>
<td>Position 4</td>
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<td>C₄, B₃, A₃, G₄⁺, D₁, G₃</td>
<td>- - ++ -</td>
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<tr>
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<td>- - ++ -</td>
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<tr>
<td>Position 6</td>
<td>262 247 220 330 294 349</td>
<td>C₄, B₃, A₃, E₁, D₁, F₁</td>
<td>- - ++ -</td>
</tr>
<tr>
<td><strong>Sequence 3</strong></td>
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<td></td>
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</tr>
<tr>
<td>Standard</td>
<td>262 294 196 294 330 392</td>
<td>C₄, D₄, G₃, D₄, E₄, G₅</td>
<td>+ - ++ +</td>
</tr>
<tr>
<td>Training</td>
<td>466 294 196 294 330 220</td>
<td>A₄⁺, D₄, G₃, D₄, E₄, A₃</td>
<td>- - ++ -</td>
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<tr>
<td>Position 1</td>
<td>440 294 196 294 330 392</td>
<td>A₄⁺, D₄, G₃, D₄, E₄, G₅</td>
<td>- - ++ -</td>
</tr>
<tr>
<td>Position 2</td>
<td>262 165 196 294 330 392</td>
<td>C₃, E₂, G₂, D₁, E₁, G₂</td>
<td>- - ++ +</td>
</tr>
<tr>
<td>Position 3</td>
<td>262 294 349 294 330 392</td>
<td>C₃, D₂, F₁, D₁, E₁, G₂</td>
<td>+ - ++ +</td>
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<tr>
<td>Position 4</td>
<td>262 294 196 523 330 392</td>
<td>C₃, D₂, G₂, C₃, E₁, G₃</td>
<td>+ - ++ +</td>
</tr>
<tr>
<td>Position 5</td>
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<td>C₃, D₂, G₂, D₁, E₁, G₂</td>
<td>+ - ++ +</td>
</tr>
<tr>
<td>Position 6</td>
<td>262 294 196 294 330 220</td>
<td>C₃, D₂, G₂, D₁, E₁, A₃</td>
<td>+ - ++ +</td>
</tr>
</tbody>
</table>

* The subscripts refer to the octave from which the note is drawn. C₄ is middle C; therefore, G₅ is G above middle C.

b A minus sign denotes a descending interval; a plus sign denotes an ascending interval.

c Indicates a change of 9 semitones.
and the parent both wore headphones carrying music to mask the nature of the trials presented to the infant. The experimenter initiated trials and recorded responses using a small control box (two push buttons mounted on a Hammond chassis) interfaced to the computer.

The infant was presented with a continuously repeating stimulus background consisting of one of the three standard melodies. Presentations of the background melody were separated by 1500-ms silent intervals. When the infant was quiet and facing directly ahead, the experimenter initiated a training trial, at which time a contrasting melody was substituted for the standard melody. This contrasting melody was presented only once, at an intensity 5 dB higher than the previously heard standard melody, after which the standard stimuli were presented repeatedly as before. During the training phase, the contrasting melody consisted of a transformation of the standard in which the initial and final tones were changed by 10 semitones (see Fig. 1 and Table 1). If the infant made a head turn of 45° or greater toward the loudspeaker, the experimenter recorded the turn. If this head turn occurred during the presentation of the contrasting sequence or the 1500-ms interval that followed (i.e., response interval of 3.7 s), one of the mechanical toys was automatically illuminated and activated for 4 s. Head turns at other times were not reinforced. If the infant responded correctly on two consecutive trials, the intensity of the contrasting melody was made equivalent to that of the standard melody. Subsequently, the infant was required to meet a training criterion of four consecutive correct responses. An infant who failed to turn to the contrasting melody on the first two trials was presented with this melody 10 dB higher than the standard on subsequent trials, until he or she responded correctly on two con-
secutive trials, at which time the intensity of the contrasting stimulus was
lowered 5 dB, and so on. The session was abandoned if the training criterion
was not met within 20 trials.

During the test phase, the standard or repeating background melody re-
mained the same as in the training phase. The procedure for presentation of
trials and recording of responses also remained the same except for the addition
of no-change trials. These no-change trials provided a measure of spontaneous
head turns or false-positive responses. Thus, in response to the experimenter’s
request to deliver a trial, the computer delivered either a change trial (with con-
trasting stimulus) or no-change trial (with the standard stimulus). The test
phase consisted of a randomized ordering of 36 trials, with 3 repetitions of
each position transformation (i.e., 18 change trials) and 18 no-change trials.

Results and Discussion

During the training phase, infants received an average of 4.5 presentations of
the background melody prior to change and no-change trials; during the test
phase, they received an average of 2.6 presentations. The data consisted of the
proportion of turns on change trials and on no-change trials for each infant on
each transformation. Figure 2 displays the percentage of responses as a func-
tion of position of the tone change for each of the three sequences. A two-
factor analysis of variance (sequence by type of trial) with repeated measures
on one factor (type of trial) was performed on the proportion correct scores;
sequence was a between-subjects factor and type of trial, a within-subjects fac-
tor. (See Myers, DiCecco, White, and Borden, 1982, for a discussion of the
application of ANOVA to data of this kind.) Note that seven types of trials
were presented, including no-change, first position change, second position
change, and so on. The analysis revealed a significant effect for trial type,
\( F(6,162) = 18.70, p < .001 \), and a significant effect for sequence, \( F(2,27) = 3.55, \)
\( p < .05 \). Table 2 gives the ANOVA table associated with this analysis.

Newman-Keuls tests on the means for different types of trials revealed
significant differences between no-change trials and change trials for each
transformation \( (p < .01 \) for all comparisons). These results indicate that in-
fants could discriminate a change in a single tone anywhere within the 6-tone
sequence. Comparisons of the various position transformations yielded no sig-
nificant effects.

In a post-hoc analysis of the influence of frequency range, the transfor-
mutations were divided into two groups: those in which the new tone was outside
the frequency range of the original melody, and those in which the new tone
was within that range. Eleven positions had transformations that extended the
frequency range, and seven positions had transformations that conserved the
range. A one-way analysis of variance performed on data from these two
groups of transformations revealed that infants were significantly better at
detecting transformations that extended the range compared to those that con-
Figure 2. Percentage of responses as a function of position of the changed tone for each sequence in Experiment 1. Asterisks indicate transformations that result in sequences with an extended frequency range relative to the standard.

Table 2
ANOVA Table for Experiment 1

<table>
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<th>SS</th>
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<th>MS</th>
<th>F</th>
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<td>Between subjects</td>
<td>2.9750</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sequence</td>
<td>0.6193</td>
<td>2</td>
<td>0.3097</td>
<td>3.55*</td>
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<td>Within subjects</td>
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<td>18.70**</td>
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<td>Within error</td>
<td>10.6346</td>
<td>162</td>
<td>0.0656</td>
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</tr>
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</table>

*p < .05  
**p < .001

served the range, $F(1,178) = 8.27, p<.005$. This suggests that infants make use of frequency range cues to detect melodic changes, not only in the case of multiple-tone changes (Trehub et al., 1984) but also for changes in a single tone. When such range cues are not available, infants can still detect changes in a single position, either on the basis of altered contour or on the basis of memory for absolute frequency.

A Newman-Keuls comparison of means for stimulus sequence showed that the significant $F$ ratio for sequence found in the main ANOVA was due to significantly lower performance on sequence 1 than on the other two sequences. This difference is likely due to the fact that only two of the transformations of sequence 1 extended the frequency range of the melody, compared to four or five for the other two sequences.
EXPERIMENT 2

Trehub et al. (1984) found that certain melodic changes (i.e., transpositions, contour-preserving transformations) were discriminable when the experimental task was relatively easy, as in Experiment 1, but not when the task was increased in difficulty by the presentation of a brief distractor sequence between melodies. Infants were able to use information about absolute frequency with the easier task but were apparently unable to do so with the more difficult task.

The purpose of the present experiment was to determine whether infants could discriminate the single tone changes of Experiment 1 under conditions of increased difficulty. Accordingly, we added the 3-tone distractor sequence used by Trehub et al. (1984, Experiment 2) between repetitions of the standard melody and between the standard and transformed melody. In addition, we sought to obtain clearer evidence of serial position effects. The evidence from Experiment 1 was inconclusive and possibly an artifact of the experimental design, in which the 3.7-s response interval began with the first tone of the altered sequence, regardless of the specific locus of change within the sequence. This resulted in the effective response interval (i.e., time available for responding following the actual occurrence of the changed tone) decreasing progressively for changes in the first through sixth position. This systematic change in response time might have obscured changes in performance as a function of the serial position of the changed tone.

In order to facilitate comparisons of performance across positions, we altered the response interval so that it began with the changed tone and was therefore effectively equivalent across positions. This change was possible in the context of the longer onset-to-onset time in Experiment 2 relative to Experiment 1.

Method

Subjects. The subjects were 33 full-term infants between 6 and 8 months of age. Three infants failed to meet the training criterion. The final sample of 30 infants consisted of 20 males and 10 females, with a mean age of 7 months, 1 day.

Apparatus and Stimuli. The equipment was the same as that of Experiment 1. The 3 standard and 18 transformed melodies from Experiment 1 were used (see Table 1). A distractor sequence consisting of three 262-Hz tones was interposed between repetitions of the background melody and between the background and test melody. The tones of the distractor sequences were 200 ms in duration, with rise and fall times of 30 ms and 200-ms intertone intervals. A 900-ms silent interval followed the target sequence, and a 950-ms silent interval followed the distractor; thus the time from the beginning of one 6-tone melody to the beginning of the subsequent 6-tone melody was about 5.1 s.
Procedure. The training and test procedures were similar to Experiment 1. Initially, the infant was trained with the stimuli of Experiment 1 (i.e., no distractor sequence) to a criterion of two consecutive correct head turns with the intensity of the altered melody 5 dB above the standard. The distractor sequence was then introduced, and the intensity of the altered melody was made equal to that of the background melody. If the infant made two consecutive errors, the intensity of the contrasting melody was increased 5 dB but the distractor continued to be present. As before, infants were required to meet a training criterion of four consecutive correct responses at equal intensity. The response interval was changed to 3 s, and the response window began with the changed note.

Results and Discussion

During the training phase, infants received an average of 2.8 presentations of the background melody prior to change and no-change trials; during the test phase, they received an average of 1.7 presentations. Head turns on change and no-change trials are shown in Fig. 3. An analysis of variance performed on the proportion correct data yielded a significant difference for trial type, $F(6,162) = 13.34, p < .001$ (see Table 3). Newman-Keuls tests were used to compare the mean performance levels of the seven types of trials (no-change, first position change, second position change, and so on). Mean proportion of turns for each of the six transformations differed significantly from the no-change trials ($p < .01$ for all comparisons), indicating that infants could discriminate all of the transformations. Furthermore, the Newman-Keuls tests

![Figure 3. Percentage of responses as a function of position of the changed tone for each sequence in Experiment 2. Asterisks indicate transformations that result in sequences with an extended frequency range relative to the standard.](image-url)
revealed significantly poorer performance on the first position change compared to changes in the third, fourth, fifth, and sixth positions \((p < .05\) for comparisons with the third and fourth positions, \(p < .01\) for comparisons with the fifth and sixth positions). Differences between the first and second position transformations approached the critical value for adjacent means at \(p = .05\).

Poor performance on first position changes relative to changes in other positions is consistent with Bentley’s (1966) findings but is at odds with other reports of first position facilitation (Ortmann, 1926; Williams, 1975). It remains to be determined, however, whether position effects would be evident with the easier task of Experiment 1, even with an altered response interval. In any case, an effective test of position effects would require numerous test melodies with varied tonal configurations.

The rates of responding on change trials in Experiments 1 and 2 appeared to be comparable (see Figs. 2 and 3), in contrast to the incidence of false alarms (i.e., turning on no-change trials). A two-factor analysis of variance revealed significantly more false alarms in Experiment 2 compared to Experiment 1, \(F(1,154) = 26.96, p < .0001\), suggesting that the increase in task demands resulted in a reduction in performance efficiency. No effects of sequence and no interaction between sequence and experiment were found, indicating that false alarm rates were constant across sequences within each experimental task.

As in Experiment 1, performance was compared on transformations that extended the frequency range of the melody and those that conserved the range. The differences were not significant, indicating that frequency range cues did not play a comparable role in the present experiment. Moreover, there were no differences in performance as a function of sequence in the main ANOVA. It would appear, then, that the elimination of frequency range as a functional discriminative cue was responsible for the absence of differences between sequences in the present experiment. The implication is that information about absolute frequency decays, either as a result of the longer time interval between melodies or the specific interference occasioned by the distractor sequence. Under conditions that do not permit the retention of specific frequency information, infants nevertheless retain global information about

<table>
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<th>Source</th>
<th>SS</th>
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<th>MS</th>
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</table>

* \(p < .001\)
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melodic contour that permits them to detect relatively small changes in melodic patterns.

The present findings add to the growing list of melody perception skills shown by infants. Not only can infants detect changes in melodic contour resulting from changes in four component tones of a 6-tone melody (Trehub et al., 1984), they can also detect changes in contour resulting from a change in a single tone. These findings cannot be based on infants’ memory for absolute frequencies alone, because infants, under comparable test conditions, are unable to detect frequency changes with three or more tones changed, when such changes do not alter the melodic contour (Trehub et al., 1984, Experiment 2).

REFERENCES


9 November 1983; Revised 5 December 1984