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Culture-General and Culture-Specific Factors in the Discrimination of Melodies

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We examined effects of a culture-general factor, pattern redundancy (number of repeated tones), on the discrimination of 5-tone melodies that differed in their adherence to Western tonal conventions. Experiment 1 evaluated the ability of 9-month-old infants to differentiate "standard" melodies from subtly altered "comparison" melodies. Greater redundancy of the standard melodies was associated with enhanced infant performance, but musical conventionality had no effect. Experiment 2 evaluated comparable abilities in 5-year-old children and musically untrained adults. Children's performance was enhanced by the redundancy of standard melodies, but the effect was greater in conventional than in unconventional contexts. The redundancy of standard melodies facilitated adults' performance in conventional but not in unconventional contexts. Thus, increasing musical exposure seems to attenuate the effects of culture-general factors such as pattern redundancy while amplifying the influence of culture-specific factors.

Key Words: music perception; auditory perception; auditory discrimination; auditory development.

Although musical cultures build on a common foundation provided by nature (i.e., the human auditory system), the peculiarity of some foreign music (e.g., Chinese, Indian) to Western ears attests to contributions from culture. Nevertheless, the age at which musical exposure or enculturation generates differential responsiveness to culturally typical (i.e., conventional) and atypical (i.e., unconventional) musical forms is unclear. We know, however, that implicit knowledge of Western scale structure requires years rather than months of musical exposure (Andrews & Dowling, 1991; Krumhansl & Keil, 1982; Lynch & Eilers, 1991; Morrongiello & Roes, 1990; Sloboda, 1985).

Tones can be organized sequentially, as in *melodies,* or simultaneously, as in *harmonies.* The structure of the resulting pattern can be described in terms of its

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simplicity, on the one hand, and its *conventionality*, on the other. In the present investigation, we examined listeners' perception of brief melodies. Our focus was on the effects of culture-general factors (i.e., pattern simplicity) and of exposure to music, particularly its culture-specific conventions. All other things being equal, a melody with simpler structure should be processed more readily than one with a more complex structure. During the process of enculturation, however, culture-specific conventions might increasingly dominate perceptual processing, attenuating or even obliterating the influence of culture-general factors such as simplicity. For example, culture-specific exposure leads adults to experience difficulty with some foreign speech contrasts that are perceptible in early infancy (Best, McRoberts, & Sithole, 1988; Best & Strange, 1992; Burnham, 1986; Polka, 1995; Polka & Werker, 1994; Trehub, 1976; Werker, Lloyd, & Pegg, 1996; Werker & Polka, 1993). Similarly, culture-specific exposure to music leads to poorer discrimination of some melodic features by adults than by infants (Trainor & Trehub, 1992).

Various structural factors contribute to the simplicity of a melody. For example, melodies with fewer component tones are more readily encoded than those with more tones (Edworthy, 1985; Watson & Foyle, 1985). Similarly, melodies with fewer changes in pitch contour (e.g., upward to downward) are simpler than those with more changes (Boltz & Jones, 1986; Morrongiello & Roes, 1990). Melodies that differ in contour are also more discriminable from one another than those with the same contour, a finding evident in adults (Dyson & Watkins, 1984; Watkins, 1985; Watkins & Dyson, 1985), children (Morrongiello, Roes, & Donnelly, 1989; Morrongiello, Trehub, Thorpe, & Capodilupo, 1985; Trehub, Morrongiello, & Thorpe, 1985), and infants (for a review see Trehub, Schellenberg, & Hill, 1997).

Simplicity in the present study was varied by means of the number of repeated tones in melodies of the same length and contour, that is, by means of *redundancy* (Garner, 1970, 1974; Lockhead & Pomerantz, 1991). We examined age-related effects of redundancy on the perception of melodies that varied in their conventionality. Specifically, we evaluated the ability of infants, children, and adults to detect subtle changes (1 semitone) in the final tone of five-tone melodies. *Conventional* melodies incorporated the major chord, a collection of three tones corresponding to the first, third, and fifth scale steps of the Western major scale (*do, mi,* and *sol,* respectively). The major chord is a Western musical archetype that evokes a highly stable representation compared to other chords (Krumhansl, Bharucha, & Kessler, 1982). For example, pieces of Western tonal music typically end with the tones of a major chord sounded simultaneously. *Unconventional* melodies incorporated the diminished chord, a collection of three tones corresponding to the seventh, second, and fourth scale steps of the major scale (*ti, re,* and *fa,* respectively). Because diminished chords evoke a relatively unstable representation (Krumhansl et al., 1982), they rarely end a piece of Western tonal music. In fact, composers of film and television soundtracks often use diminished chords to create a sense of tension or impending doom. We created high- and low-redundancy versions of the conventional and unconventional melodies. The low-redundancy versions had fewer repeated tones (i.e., a larger set of distinct tones), one of the tones being from outside the chord on which the melodies were based.

Our listeners were tested on their ability to discriminate *high-redundancy* from *low-redundancy* melodies. When the *standard* melody (presented first) had high redundancy, the *comparison* melody (presented second) had low redundancy; conversely, when the standard had low redundancy, the comparison had high redundancy. We predicted greater ease of processing and, consequently, better discrimination in the former case (high-redundancy standards) compared to the latter case (low-redundancy standards). In other words, we predicted performance *asymmetries* such that listeners would be better able to distinguish Melody A (high-redundancy standard) from Melody B (low-redundancy comparison) than Melody B (low-redundancy standard) from Melody A (high-redundancy comparison).

Asymmetries are common in studies of auditory discrimination. When adults judge whether the rhythm of two tone sequences is the same or different, performance is better when the standard sequence has a regular rhythm and the comparison sequence an irregular rhythm than when the standard and comparison are reversed (Bharucha & Pryor, 1986). Similar findings have been reported for chords (Bharucha & Krumhansl, 1983) and melodies (Bartlett & Dowling, 1988); stable and unstable musical stimuli are more distinct from one another when the stable stimulus precedes the unstable stimulus. Moreover, adults', children's, and infants' discrimination of intervals (i.e., pairs of tones) is better when the standard interval has a consonant (i.e., pleasant-sounding), small-integer frequency ratio (e.g., 3:2) and the comparison interval has a dissonant (i.e., unpleasant-sounding), large-integer ratio (e.g., 45:32) compared to the reverse situation (Schellenberg & Trehub, 1994a, 1996a; Trainor, 1997).

One explanation of these asymmetries in discrimination abilities concerns the perceptual stability of the standard pattern. According to Acker, Pastore, and Hall (1995; see also Acker & Pastore, 1996), well-structured tone patterns function as perceptual *anchors*, facilitating the encoding of pattern details. As a result, listeners more accurately detect changes to well-structured than to poorly structured patterns. From Garner's (1970, 1974) perspective, redundant patterns have fewer alternatives and are considered "better" (i.e., more distinct) structures than less redundant patterns. For example, redundant patterns can be considered part of a relatively small set that is restricted to other redundant patterns; nonredundant patterns have redundant as well as nonredundant alternatives. Garner's perspective and that of Acker et al. generate the same prediction: A high-redundancy standard melody and a low-redundancy comparison melody should yield more accurate discrimination than a low-redundancy standard and a high-redundancy comparison.

Another explanation of performance asymmetries comes from music theorists (Langer, 1953; Meyer, 1973; Narmour, 1990), who contend that patterns of "tension" and "resolution" or of "implication" and "realization" are central to the process of music listening. For example, a musical pattern that is poorly structured would be perceived as unstable or incomplete, requiring resolution by a more stable pattern. Thus, a comparison pattern that resolves the preceding, "incomplete" standard pattern "completes" it in some sense, generating a larger perceptual unit that blurs the distinctions between the two patterns. Bharucha (1984) found that adult listeners' ability to detect alterations to melodies is poor when new, unstable tones are resolved by subsequent, more stable tones. Similarly, adults have more difficulty noticing when an unstable chord in a sequence of chords is replaced by a stable chord than when it is replaced by another unstable chord (Bharucha & Krumhansl, 1983). Because such effects depend on culture-specific knowledge, they should increase with increasing musical exposure.

There is unequivocal evidence of processing advantages for conventional over unconventional melodies (with regard to Western tonal music). For example, Western adults exhibit superior retention of typical melodies (e.g., those based on the major scale) compared to atypical melodies (e.g., Dowling, Kwak, & Andrews, 1995; Lynch & Eilers, 1992; Lynch, Eilers, Oller, & Urbano, 1990; Lynch, Eilers, Oller, Urbano, & Wilson, 1991; Trehub, Schellenberg, & Kamenetsky, 1999; Watkins, 1985). This processing advantage can arise from incidental musical exposure or from formal musical training (Dowling et al., 1995; Lynch & Eilers, 1992; Lynch et al., 1990, 1991; Trehub et al., 1999; Watkins, 1985). Moreover, adult listeners prefer melodies that conform to the major scale over those that do not, regardless of musical training (Cross, Howell, & West, 1983). Children 6 and 7 years of age assign higher "goodness" ratings to melodies constructed entirely from tones of the major scale than to melodies with some nonscale tones (Krumhansl & Keil, 1982).

Additional evidence of exposure effects comes from differential responsiveness to patterns that occur with greater or lesser frequency. For example, chords from the key of C are perceived to be more closely related in typical contexts (the key of C) than in atypical contexts (the key of F#) (Bharucha & Krumhansl, 1983). Even infants 6–10 months of age exhibit processing advantages for conventional over unconventional musical structures (Cohen, Thorpe, & Trehub, 1987; Lynch & Eilers, 1992; Lynch, Short, & Chua, 1995; Schellenberg & Trehub, 1996b; Trainor & Trehub, 1993a, 1993b; Trehub et al., 1999; Trehub, Thorpe, & Trainor, 1990). In principle, exposure and learning could account for 6-month-olds' facility with some Western musical structures (Lynch et al., 1995). Alternatively, processing predispositions of various kinds could account for the apparent conventionality effects in infancy (Schellenberg & Trehub, 1994b, 1996b; Trehub et al., 1999; Trehub & Trainor, 1993). In contrast to previous studies, in which contributions from conventionality and other factors were difficult to tease apart, the present study had orthogonal manipulations of redundancy and conventionality.

We tested listeners on their ability to detect subtle changes in melodies that varied in terms of their redundancy, either in the conventional context of the major chord or in the unconventional context of the diminished chord. As noted, we expected superior performance for standard melodies with high redundancy relative to those with low redundancy (fewer repeated tones). In other words, we predicted that redundant melodies would function as perceptual anchors, in line with Acker et al. (1995). We expected this effect to change over the course of development, with performance becoming increasingly influenced by the conventionality of the stimulus context. For example, adults' extended exposure to music (incidental or formal) might generate greater effects of redundancy in conventional than in unconventional contexts. Our primary goal, then, was to determine whether pattern redundancy would interact with the conventionality of the stimulus context, and whether this interaction would change over the course of development.

Studies of auditory pattern (i.e., music) processing often focus on musically trained adults (for a review see Smith, 1997) and children (Morrongiello & Roes, 1990; Morrongiello et al., 1989). By contrast, our focus was on "ordinary" musical enculturation that results from everyday exposure to music. The distinction between ordinary musical competence and musical expertise is particularly relevant in Western cultures, where relatively few adults become experts, yet most nonexperts can recognize hundreds of songs. Moreover, the effects of incidental exposure seem to differ qualitatively as well as quantitatively from the effects of formal musical training (Gérard & Auxiette, 1988; Lynch et al., 1990; Morrongiello & Roes, 1990; Morrongiello et al., 1989; Spiegel & Watson, 1984). Smith (1997) advocates the inclusion of novices in the burgeoning science of music cognition for "a more balanced and broader picture of the whole population that listens to music in every human culture" (p. 257).

In Experiment 1, we examined 9-month-old infants' perception of melodies that varied in their redundancy and conventionality. Infants heard a repeating standard melody and were tested on their ability to detect the substitution of a comparison melody for the standard. In Experiment 2, we tested musically untrained 5-year-old children and adults with a same–different task that accommodated the attentional limitations of the children. All of the listeners were required to detect a 1-semitone change in *relative* pitch (frequency ratio or interval size) rather than a change in *absolute* pitch. To prevent listeners from relying on absolute-pitch cues, consecutive melodies were always presented in *transposition.* In other words, absolute frequencies changed from one presentation to the next, but the frequency relations between tones remained constant (except for a 1-semitone displacement of the final tone of comparison melodies). Because the standard melody remained unchanged (except for pitch level) throughout the test session, the task involved "minimal uncertainty" (Watson, 1987). In contrast to psychoacoustic experiments, which aim to specify listeners' sensory capabilities or their best performance after extended practice (e.g., Kidd & Watson, 1996), our interest was in the "response proclivities" (Espinoza-Varas & Watson, 1989) of untrained listeners.

EXPERIMENT 1

In the present experiment, we examined 9-month-old infants' perception of melodies differing in redundancy and conventionality. We expected infants to exhibit superior processing of more redundant compared to less redundant melodies. In line with previous research (e.g., Schellenberg & Trehub, 1994a, 1996a, 1996b), superior processing should be reflected in enhanced detection of subtle alterations in such melodies. Thus, we predicted relatively good discrimination when standard melodies were more redundant than comparison melodies, and relatively poor discrimination when comparison melodies were more redundant than standard melodies. Equivocal consequences of musical exposure in infancy (Lynch & Eilers, 1992; Lynch et al., 1990, 1995; Trainor & Trehub, 1992) did not permit clear predictions regarding pattern conventionality. Even if musical exposure resulted in conventionality effects, it seemed unlikely that these effects would outweigh or interact with the effects of redundancy.

Method

Participants. The participants were 60 healthy, full-term infants (33 males, 27 females) who were 8 months 10 days to 9 months 15 days of age ($M = 9$ months 1 day; $SD = 8.9$ days) and whose families responded to letters distributed in the local community. Volunteer families were of middle-class background and primarily of European descent. All infants were free of colds or ear infections at the time of testing and had no family history of hearing problems. An additional 14 infants were excluded from the final sample for failing to meet the training criterion ($n = 6$), minor procedural difficulties ($n = 1$), fussing ($n = 6$), or parental interference ($n = 1$).

Apparatus. Testing took place in a double-wall sound-attenuating booth with a computer controlling all equipment. Stimuli were produced by two tone generators, with sound levels controlled by two attenuators. The tones were turned on and off by rise/fall switches and presented by means of a stereo amplifier and loudspeaker. Trials were initiated and responses recorded by a customized button box connected to the computer. Four mechanical toys, which were housed in a smoked Plexiglas box under the loudspeaker, were illuminated and activated individually (in random order) as feedback for correct responding.

Stimuli. Stimulus melodies are illustrated in Fig. 1. The melodies were sequences of five contiguous pure tones with a simple rise–fall contour. The second and third tones were each higher than the immediately preceding tones; the fourth and fifth tones were each lower than the immediately preceding tones. Individual tones were 400 ms with 10-ms linear onsets and offsets, resulting in melodies of

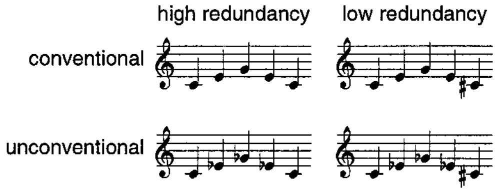

FIG. 1. Illustration of stimulus melodies in Experiments 1 and 2.

2-s duration. Four testing conditions were formed in a 2 × 2 design. Each condition had a standard melody and a comparison melody that differed from the standard by a 1-semitone displacement of its final (fifth) tone. All melodies were structured so that their second and fourth tones were identical. In the two conventional conditions (Fig. 1, top), the first four tones of standard and comparison melodies were drawn from the major triad (*do-mi-sol-mi*). In the two unconventional conditions (bottom), the first four tones of standard and comparison melodies were drawn from the diminished triad (*ti-re-fa-re*).

In the *high-redundancy, conventional* condition, the standard melody (Fig. 1, upper left) had three different component tones belonging to a single major triad, with *two* repeated tones (the first and fifth tones were identical, as were the second and fourth tones). The altered comparison melody (upper right) was identical to the standard except that it had four different component tones (only *one* repeated tone) because the fifth tone was displaced upward by 1 semitone (frequency increased by approximately 6%) from the standard. The standard and comparison melodies were simply reversed for the *low-redundancy, conventional* condition, which made the standard melody less redundant than the comparison melody. The *high-redundancy, unconventional* condition was identical to its conventional counterpart except that the second, third, and fourth tones of standard and comparison melodies were each displaced downward by 1 semitone. Specifically, the high-redundancy standard melody (lower left) conformed to an unconventional diminished chord, having two repeated tones, and the low-redundancy comparison melody (lower right) had only one repeated tone. Standard and comparison melodies were reversed for the *low-redundancy, unconventional* condition, the standard being less redundant than the comparison. Although the direction of tone displacements (upward, downward) differed for high-redundancy and low-redundancy conditions, this factor has had no impact on performance in previous investigations of infants (Trainor, 1997), children (Schellenberg & Trehub, 1996a), and adults (Schellenberg & Trehub, 1994a; Trainor, 1997).

Procedure. Infants sat on their parent's lap facing the experimenter in the sound-attenuating booth with the loudspeaker and toys located 45° to their left. Parent and experimenter wore headphones to keep them unaware of the occurrence of change or no-change trials. Infants, who were assigned to one of six conditions (n = 15), heard

FIG. 2. Illustration of the go/no-go method in Experiment 1 (high-redundancy, conventional condition). The upper part shows two repeating standard sequences, a *no-change* trial, and another standard sequence; all four sequences are identical except for pitch level. The lower part shows two repeating standard sequences followed by a *change* trial (final tone displaced upward by 1 semitone) and another standard sequence. Head turns were monitored during trials.

a standard melody presented repeatedly, with successive repetitions separated by 1.2 s of silence. The procedure is illustrated in Fig. 2. In all conditions, successive repetitions of the standard melody were presented in transposition. Specifically, the absolute pitch of the tones was changed from presentation to presentation but the relations (frequency ratios) between tones remained constant (except on change trials). Transpositions shifted pitch upward or downward by 5 or 7 semitones. Transpositions to "closely related keys" (Aldwell & Schachter, 1989) were selected because these shifts in pitch are the most common in Western music and should maximize performance (Trainor & Trehub, 1993a) and promote culture-specific responding. The first tone of the melody at the lowest pitch level was middle C (C_4, or 262 Hz; tuning based on A_4 = 440 Hz). Other melodies started with G_4 (392 Hz), D_4 (294 Hz), A_4 (440 Hz), or E_4 (330 Hz).

The experimenter used hand puppets to encourage infants to look directly in front of them rather than leftward to the locus of the repeating melodies. Whenever the infant looked directly ahead, the experimenter pressed a button to indicate the infant's "readiness" for a trial. Trials were of two types: *change* trials (presentation of a single comparison melody that differed from the preceding and succeeding standard melodies) and *no-change* trials (presentation of another standard melody that was identical to the preceding or succeeding standard melodies except for its pitch level). The computer presented trials only if the infant was "ready" (i.e., looking directly ahead) and at least three repetitions of the standard melody had been presented since the preceding trial. Whenever the infant turned toward the loudspeaker, the experimenter pressed another button on the button box, but the computer recorded only those turns that occurred within 3.2 s after the onset of the potentially changed (fifth) tone. Correct turns (i.e., turns on change trials within this response window) were automatically followed by the illumination and activation of one of the four mechanical toys for 4 s. Turns at other times had no consequence.

Prior to the test phase, infants completed a training phase designed to familiarize them with the procedure, particularly with the entertaining consequences of turning to a change in the melody. The training phase was identical to the test

TABLE 1
Mean Number of Hits and False Alarms in Experiments 1 (Infants) and 2 (Children and Adults)

	Infants	Children	Adults
	Conventional high-redundancy		
Hits	6.4 (2.2)	9.1 (2.6)	11.0 (1.2)
False alarms	3.6 (1.6)	2.1 (1.4)	1.7 (2.1)
	Conventional low-redundancy		
Hits	4.0 (1.6)	4.9 (2.4)	5.2 (1.8)
False alarms	4.0 (1.0)	5.2 (2.3)	5.9 (2.9)
	Unconventional high-redundancy		
Hits	6.3 (2.3)	6.9 (2.4)	8.2 (3.4)
False alarms	4.5 (1.6)	3.7 (2.0)	2.2 (1.3)
	Unconventional low-redundancy		
Hits	3.7 (2.4)	5.5 (3.4)	7.7 (2.8)
False alarms	3.0 (2.0)	5.5 (2.8)	2.6 (2.5)

Note. Perfect performance is 12 hits and 0 false alarms. Standard deviations are in parentheses.

session with the following exceptions: (1) Comparison melodies during the practice sessions incorporated a much larger change than they did during the test session—the fifth tone of the standard melody was displaced upward in pitch by an octave, or 12 semitones; (2) only change trials were presented; and (3) 5-dB increases in intensity were used initially to help draw attention to the changes (see Trehub et al., 1997). The training phase was terminated automatically once infants responded correctly on four successive trials without the aid of increases in intensity. Only infants who achieved the training criterion in fewer than 30 trials proceeded to the test phase. The test phase consisted of 24 trials, 12 change and 12 no-change, in pseudorandom order, with the constraint of a maximum of 2 consecutive no-change trials.

Results and Discussion

Mean numbers of hits and false alarms (i.e., the number of head turns on change and no-change trials, respectively) for each condition are provided in Table 1. For statistical analyses, hits and false alarms were converted to discrimination (d') scores for each infant by means of yes/no tables from signal detection theory (Elliott, 1964). Before converting to d' scores, however, 0.5 was added to the hits and false alarms of each infant and 1.0 to the total number of trials (following Thorpe, Trehub, Morrongiello, & Bull, 1988). This transformation is warranted when relatively small numbers of trials can inadvertently produce

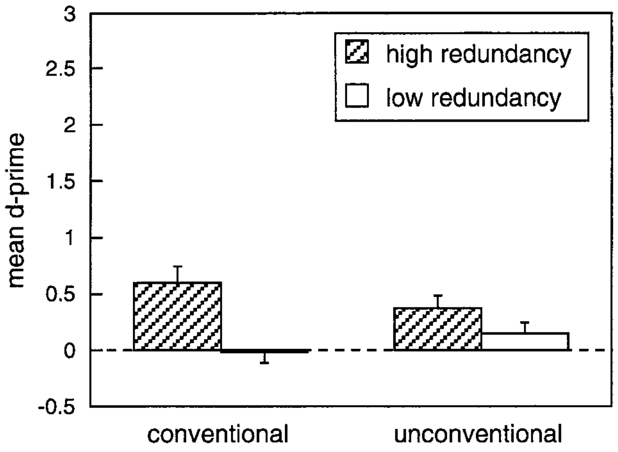

FIG. 3. Mean discrimination (d') scores for infants in Experiment 1 as a function of the redundancy manipulation and the conventionality of the stimulus contexts. Error bars are standard errors.

perfect hit rates (12 of 12) or false-alarm rates (0 of 12) and, therefore, infinite d' scores. Mean d' scores are shown in Fig. 3.

Separate one-sample t tests were used to compare infants' performance with chance levels of responding (i.e., equal number of head turns on change and no-change trials, or $d' = 0$) for each condition. Infants' performance was significantly better than chance in the high-redundancy, conventional condition, $t(14) = 4.12$, $p = .001$, and in the high-redundancy, unconventional condition, $t(14) = 3.54$, $p = .003$. Performance was at chance levels in both low-redundancy conditions. A 2×2 analysis of variance (ANOVA) with redundancy and conventionality as independent variables confirmed that performance was better in the high-redundancy conditions than in the low-redundancy conditions, $F(1, 56) = 13.27$, $p < .001$. The conventionality of the stimulus context had no effect on performance and did not interact with redundancy.

Hence, 9-month-olds' discrimination of melodies was influenced by culture-general factors such as redundancy (in this case, the number of repeated tones), but not by culture-specific conventions. The absence of conventionality effects raises questions about previous claims of musical exposure effects in infancy (Lynch & Eilers, 1992; Lynch et al., 1995). Instead, the present findings offer support for interpretations that link differential responding in infancy to processing predispositions (Schellenberg & Trehub, 1996b; Trainor & Trehub, 1993a, 1993b; Trehub, 2000) or culture-general factors (Lynch et al., 1990).

EXPERIMENT 2

In the present experiment, we examined 5-year-olds' and adults' perception of pure-tone melodies differing in redundancy and conventionality. Although the basic experimental design mirrored that of Experiment 1, the go/no-go task was replaced with a simplified same–different (AX) procedure that accommodated the attentional and cognitive limitations of young children. Our use of the same procedure with both age groups afforded: (1) direct comparisons between children and adults and (2) a more complete account of age-related influences of conventionality and redundancy on the perception of melodies.

Because long-term exposure to Western music affects the perception of melodies (e.g., Lynch & Eilers, 1992; Lynch et al., 1990, 1991; Trainor & Trehub, 1992; Trehub et al., 1999), we expected that the influence of tone redundancy on adults' performance would vary as a function of the conventionality of the stimulus context. Although standard melodies with greater redundancy were expected to facilitate the detection of subtle changes, overlearning of Western musical structures might reduce the relevance of redundancy in unconventional contexts. As active participants in their musical culture, preschool children are also likely to be sensitive to the frequency of commonly occurring musical structures, unlike 9-month-olds (Experiment 1). Nonetheless, despite 5- and 6-year-old children's implicit knowledge of some musical features (Cuddy & Badertscher, 1987; Trainor & Trehub, 1994), their knowledge of Western musical structures remains limited (Krumhansl & Keil, 1982; Trainor & Trehub, 1994). We considered it unlikely, then, that the unconventional stimulus contexts of the present experiment would attenuate the effects of redundancy as much for children as they would for adults.

Method

Participants. The 60 child participants (24 males, 36 females), who were 5 to 5.5 years of age (M = 5; 3; 14, SD = 43 days), were recruited from the local community, as in Experiment 1. Participants had no family history of hearing loss, no personal history of repeated ear infections, no known health problems, and no cold or infection at the time of testing. An additional 13 children were excluded from the final sample for failing to meet the training criterion ($n = 9$), technical problems during testing ($n = 1$), or poor attention to the task ($n = 3$). Children received a token gift for their participation. The 40 adult participants (18 men, 22 women), who were recruited from introductory courses in psychology, received partial course credit; none had ever taken private music lessons.

Apparatus and stimuli. Identical to those in Experiment 1.

Procedure. Child and adult listeners were tested individually. Each child sat on a chair facing the experimenter, with the loudspeaker and reinforcing toys 45° to the child's left. When the child was attentive and looking directly ahead, the experimenter pressed a button to signal to the computer the child's readiness for a trial. Each trial consisted of three stimulus melodies (see Fig. 4), the first two being repetitions (in transposition) of the standard melody. On change trials, the comparison (third) melody differed from the two standard melodies that preceded it; on no-change trials, the comparison melody was identical to the preceding standard melodies (except for pitch level). Children were required to indicate

FIG. 4. Illustration of the same/different method in Experiment 2 (high-redundancy, conventional condition). The upper part—a *same* trial—shows a standard sequence followed by two sequences identical to the standard except for pitch level. The lower part—a *different* trial—shows three sequences: a standard sequence, another sequence identical to the standard, and an altered comparison sequence (final tone displaced upward by 1 semitone). On each trial, adults and children compared the third sequence to the first two and responded "same" or "different."

whether they heard a change in the final pattern by nodding and saying "yes" if they did and by shaking their head and saying "no" if they did not. The experimenter, who wore headphones to mask the distinction between change and no-change trials, pressed one button on the button box for children's affirmative responses and another for their negative responses.

There were four conditions, with 15 children assigned to each condition. Standard and comparison melodies of the four conditions were identical to those of Experiment 1 (see Fig. 1), with the melodies transposed to closely related keys. The lowest tone of the first melody was either C_4 (262 Hz) or D_4 (294 Hz), selected randomly. The second melody was always transposed upward by 7 semitones (e.g., from C_4 to G_4); the third presentation was always transposed downward by 5 semitones (e.g., from G_4 to D_4).

At the beginning of the session, the experimenter introduced the concept of transpositions by singing "Happy Birthday" without words and asking the child to identify the song. She then sang "Happy Birthday" twice more in different keys to demonstrate that a song maintains its identity across transpositions. Children were introduced to the testing procedure with two demonstration trials: a no-change trial followed by a change trial. Familiarization with the procedure continued during a brief training phase. In the demonstration and training phases, the to-be-detected change was considerably larger than it was in the test phase (i.e., the fifth tone of the comparison melody was shifted upward by an octave, as in Experiment 1). Only children who produced 4 consecutive correct responses within 20 training trials proceeded to the test phase, which consisted of 12 change trials and 12 no-change trials in pseudorandom order (no more than 2 consecutive no-change trials). Correct "yes" and "no" responses resulted in illumination and activation of one of the four mechanical toys for 4 s.

The adult procedure was identical, with the following exceptions: (1) 10 adults were assigned to each of the four conditions, (2) participants made their responses directly using the button box, and (3) they were alone in the sound-attenuating booth during the test phase.

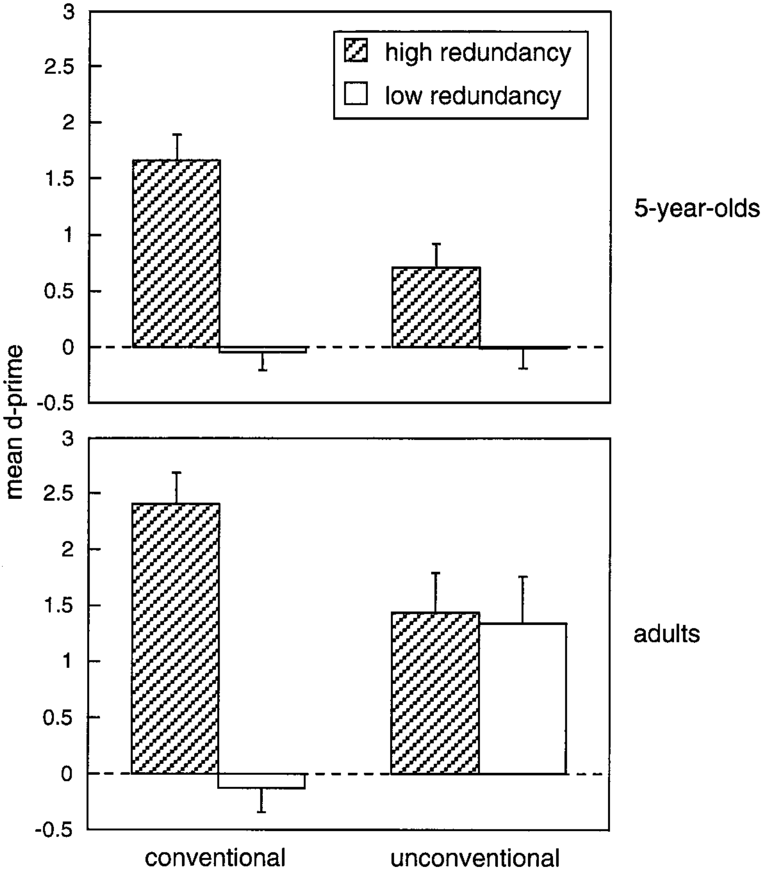

FIG. 5. Mean discrimination (d') scores for children (top) and adults (bottom) in Experiment 2 as a function of the redundancy manipulation and the conventionality of the stimulus contexts. Error bars are standard errors.

Results and Discussion

Hits (responding "yes" on change trials) and false alarms (responding "yes" on no-change trials; see Table 1) were converted to d' scores, as in Experiment 1. Mean levels of performance are shown in Fig. 5. One-sample t tests indicated that children's discrimination performance was significantly above chance levels in the high-redundancy, conventional condition, $t(14) = 7.03$, $p < .001$, and in the high-redundancy, unconventional condition, $t(14) = 3.42$, $p = .004$, but not in either of the low-redundancy conditions. Adults performed significantly better than chance in the high-redundancy, conventional condition, $t(9) = 9.12$, $p < .001$, in the high-redundancy, unconventional condition, $t(9) = 4.02$, $p = .003$, and in the low-redundancy, unconventional condition, $t(9) = 3.19$, $p = .011$, but not in the low-redundancy, conventional condition.

A three-way ANOVA with redundancy (two levels), conventionality (two levels), and age group (two levels) as independent variables revealed a reliable three-way interaction, $F(1, 92) = 4.15$, $p = .045$. This finding confirmed our prediction of differential influences of unconventional contexts on children's and adults' perception of redundant melodies. Accordingly, subsequent analyses examined the joint effects of redundancy and conventionality separately for children and for adults.

The influence of redundancy and conventionality on children's discrimination performance was examined with a two-way ANOVA. A significant interaction between factors, $F(1, 56) = 6.08$, $p = .017$, precluded clear interpretation of the main effects. Accordingly, follow-up tests of simple effects were used to examine the influence of redundancy for conventional and unconventional contexts. Children exhibited superior performance for high-redundancy standard melodies in conventional contexts, $F(1, 56) = 36.50$, $p < .001$, with the redundancy manipulation accounting for 57% of the variance. A similar pattern was evident in unconventional contexts, $F(1, 56) = 6.52$, $p = .013$, although the magnitude of the effect (explaining 19% of the variance) was weaker.

An identical two-way (redundancy by conventionality) ANOVA on the adult data revealed a significant interaction between main effects, $F(1, 36) = 14.38$, $p < .001$. Follow-up tests of simple effects confirmed that the influence of the redundancy manipulation was statistically reliable in conventional contexts, $F(1, 36) = 30.86$, $p < .001$, accounting for 76% of the variance. For unconventional contexts, however, the redundancy effect was nonsignificant and explained less than 1% of the variance. To test the hypothesis that resolution effects, which impair performance, were greater in conventional than in unconventional contexts, performance was compared in the two low-redundancy conditions. Performance was significantly worse in the low-redundancy, conventional condition than in the low-redundancy, unconventional condition, $F(1, 36) = 10.41$, $p = .003$, which is consistent with the suggestion that resolution effects are likely to emerge when mature listeners are tested in conventional contexts. (This final comparison was not conducted for infants or children because performance was at chance levels in both low-redundancy conditions.)

In short, redundancy influenced 5-year-olds' performance in unconventional as well as conventional contexts. By contrast, redundancy effects in adults were limited to conventional contexts.

GENERAL DISCUSSION

The present findings reveal age-related changes in the discrimination of melodies as a function of culture-general factors such as redundancy and culture-specific factors such as conventionality. Listeners of all ages were better at detecting changes from more redundant to less redundant melodies than they were at detecting the reverse changes. Redundant melodies (more repeated tones) appear to be encoded with greater accuracy than less redundant melodies, promoting enhanced detection of subtle changes. Increasing age, with its attendant increase in musical exposure, leads to progressively greater influences of conventionality and the gradual attenuation of redundancy effects in unconventional contexts. Specifically, 9-month-old infants exhibited enhanced discrimination of melodies with more repeated tones, an effect that was independent of the conventionality of the melodies. Preschool children showed similar effects of redundancy, although such effects were greater in conventional than in unconventional contexts. For adults, the redundancy manipulation affected performance *only* in conventional contexts.

The developmental findings of the present investigation have intriguing parallels with those observed in speech perception contexts. For example, prelinguistic infants perceive many of the acoustic distinctions that signal phonemic contrasts in different languages well before they acquire phonological knowledge (Best et al., 1988; Burnham, 1986; Polka & Werker, 1994; Trehub, 1976; Werker & Lalonde, 1988; Werker & Tees, 1984). Indeed, a common consequence of such knowledge is poor performance on nonnative contrasts (Best & Strange, 1992; Polka, 1995; Werker & Lalonde, 1988; Werker & Polka, 1993). The presumption is that adults, despite superior auditory sensitivity, assimilate two or more nonnative phones to the same native phonemic category, resulting in discrimination failures (Best, 1992, 1993). In other words, poor discrimination can arise from culture-specific coding. Just as the acquisition of a phonological system alters one's perception of conventional (native) and unconventional (nonnative) sound patterns, so may the acquisition of a musical system refocus attention so that effects of culture-general properties (e.g., redundancy) are weakened when culture-specific expectations are violated. Although the course of musical enculturation is protracted (e.g., Krumhansl & Keil, 1982; Lynch & Eilers, 1991; Trainor & Trehub, 1994) relative to primary language acquisition, once the process is complete, listeners have difficulty extracting some aspects of structure from musiclike patterns presented in musically unconventional contexts. Similarly, the redundancy of speech sequences may be more difficult to notice in the context of languages whose phonological systems differ substantially from one's own (e.g., Mandarin for native speakers of English).

The present findings also have parallels in music processing. Adults often perform better on discrimination tasks in which the to-be-compared melodies are presented in closely related keys rather than in unrelated (or distantly related) keys (e.g., Cuddy, Cohen, & Mewhort, 1981; Cuddy, Cohen, & Miller, 1979; Sloboda & Edworthy, 1981). Trainor and Trehub (1993b), who found key-distance effects for infants as well as adults, attributed the finding to pitches in closely related keys (e.g., C and G) being related to one another by small-integer frequency ratios (3:2 in the case of C and G). For adults, the advantage for closely related keys was apparent for conventional melodies (the major triad) but not for unconventional melodies (the augmented triad). For infants, however, the effect was evident for unconventional as well as conventional melodies. Thus, an initial, unconditional bias favoring transpositions with small-integer ratios becomes selective after some period of culture-specific exposure. In another study (Trehub et al., 1999), infants exhibited processing advantages for familiar and artificial musical scales whose successive tones were separated by unequal steps rather than by equal steps. By contrast, adults performed well on the unequal-step major scale, but poorly on unfamiliar scales, whether the steps were of equal or unequal size. Again, culture-specific exposure changes a broad initial bias favoring unequal-step scales to a selective bias for *familiar* (unequal-step, major or minor) scales. In the present study, long-term exposure to music led to selective narrowing of an initial processing bias for high-redundancy melodies.

Redundant melodies in the present study were designed so that the pitch of component tones was symmetric about the midpoint of the third tone (see Fig. 1). These symmetric melodies were selected for the simplicity of their contour because infants are particularly sensitive to the pitch contour of melodies (see Trehub et al., 1997). The temporal nature of auditory stimuli makes it unlikely that symmetry per se facilitates processing to the same extent as it does with visual stimuli (Garner, 1974; Palmer, 1991). For mirror-image symmetry to be perceptually relevant in audition, melodies presented in exactly the reverse order (e.g., *do re mi; mi re do*) would have to be recognizable immediately. Such symmetry is unlikely to confer processing advantages that are comparable to exact repetitions of the melodies (e.g., *do re mi; do re mi*). Nonetheless, reversals may facilitate processing relative to randomly ordered melodies with comparable redundancy. Our finding of redundancy effects for listeners of all ages is consistent with Lufti's (1993) model of auditory pattern perception, which predicts that the ease of detecting changes in a melody is a function of the relative duration of the changed tone (higher proportion of total melody duration = greater ease; see also Kidd & Watson, 1992). Our results indicate, however, that enhanced performance is also evident when relative duration is extended by repetition.

The present findings can also be interpreted in the context of *prototypes* (Rosch, 1975; Trehub & Unyk, 1991). Prototypical instances of stimuli (e.g., robins, the reddest red) act as frames of reference for other stimuli in the same category (e.g., other birds, other shades of red). They are more similar to other within-category instances (e.g., cardinals, burgundy) than are nonprototypes, but more distinct from noncategory instances (e.g., varieties of fish, shades of green). Although the major chord is clearly an archetypal or prototypical pattern, the concept of prototypicality is problematic for domains such as music in which categories are not readily definable for musically inexperienced listeners. In the case of speech, where phonemic categories are readily defined, adults and infants show poorer discrimination in the context of prototypical standards compared to nonprototypical standards (Iverson & Kuhl, 1995; Kuhl, 1991; Kuhl, Williams, Lacerda, & Stevens, 1992; but see Sussman & Gekas, 1997; Sussman & Lauckner-Morano, 1995). The prototype is considered to function as a "perceptual magnet" (Kuhl, 1991), shrinking the apparent distance between stimuli within the category. Unfortunately, proponents of perceptual magnets have not attempted to identify performance asymmetries such as those observed in the present investigation, nor have they compared between-category discrimination for prototypical and atypical examples.

In the context of the present investigation, once sufficient exposure elevates the major chord to highly conventional, "good," or prototypical status, it becomes relatively unique and, therefore, distinct from subtly altered patterns. By contrast, the diminished chord, a nonprototypical pattern, remains part of a large, poorly differentiated category. It is not surprising, then, that adults more readily detect changes to a well-tuned major chord than to a mistuned chord (Acker et al., 1995), just as they more readily detect changes to melodies based on the major chord than to those based on the diminished chord.

Adults' difficulty detecting redundant comparison melodies in Experiment 2 is interpretable with reference to resolution effects such as those described by Bharucha (1984; Bharucha & Krumhansl, 1983). Not only were redundant melodies perceptually distinct as standard stimuli, but they were especially indistinct as comparison stimuli, perhaps because they resolved or completed the unstable standard stimuli. For mature listeners, then, discrimination seems to be a joint function of the redundancy, and consequent stability, of the standard melody, which enhances discrimination, and the redundancy of the comparison melody, which may impair discrimination. It is important to note that such resolution effects were evident only for adult listeners tested in conventional contexts. Thus, poor performance on redundant comparison melodies may arise from complex developmental processes, limiting the phenomenon to mature listeners tested in specific contexts. Before exposure effects are well established, however, the discrimination of subtle stimulus differences (e.g., a 1-semitone change) depends primarily on the relative simplicity (e.g., redundancy) of the standard melody.

For all age groups, the highest levels of performance occurred in the high-redundancy, conventional condition. By contrast, none of the groups performed above chance levels when the standard and comparison melodies were reversed. Our finding of performance asymmetries is consistent with other asymmetries in auditory pattern perception (Bharucha & Krumhansl, 1983; Bharucha, Olney, & Schnurr, 1985; Bharucha & Pryor, 1986; Schellenberg & Trehub, 1994a, 1996a; Trainor, 1997; Trainor & Trehub, 1993a). In general, adults more readily detect changes in conventional patterns than in unconventional patterns (e.g., Acker et al., 1995). Moreover, they rate conventional auditory patterns as more distinct from unconventional patterns than unconventional from conventional patterns. Indeed, the present asymmetries parallel those of Bartlett and Dowling (1988), whose participants rated *diatonic* standard melodies (i.e., all tones from a single scale) as more distinct from nondiatonic comparison melodies than nondiatonic standards from diatonic comparisons. Our findings indicate that "good" standard melodies—those with few alternatives (Garner, 1970)—are more distinct from "poor" comparisons (i.e., less similar to them) than are "poor" standards from "good" comparisons. In the present study, however, well-formedness arose from culture-general (redundancy) and culture-specific (conventionality) properties. The results indicate, moreover, that the properties of a well-formed or "good" melody change with increasing exposure to music. Initially, redundancy makes a substantial contribution to the well-formedness of a melody and, therefore, to its ease of processing. Musical exposure makes progressively increasing contributions, sometimes doing so at the expense of culture-general contributions.

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