Infants' Perception of Good and Bad Melodies

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INFANTS' PERCEPTION OF *GOOD* AND *BAD* MELODIES

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Infants 7 to 10 months of age were exposed to repetitions of one of three melodies in transposition, the three melodies exhibiting different degrees of conformance to Western music structure. One was a *good* Western melody, consisting of notes from the diatonic scale; another was a *bad* Western melody with notes drawn from the chromatic scale but not from any single diatonic scale; and the third was a *bad* non-Western melody with notes not drawn from the chromatic scale. The infants were first trained to respond (i.e., turn) to a single-position change of three semitones in the standard melody (for visual reinforcement). They were subsequently tested for their discrimination of a one-semitone change, with all changed melodies presented in transposition. Infants discriminated the semitone change in the context of the *good* Western melody but not the *bad* Western or the *bad* non-Western melody. We discuss the structural and experiential factors that may underlie such performance differences.

Auditory patterns that are relatively easy to remember and differentiate from other patterns can be said to exhibit *good form*. Nevertheless, there has been limited progress in specifying the critical properties of such patterns or the relevant perceptual processes. In the visual domain, several attempts to characterize *good form* have implicated basic coding properties of the visual system (Hoffman & Dodwell, 1985) or general Gestalt principles (Garner, 1970, 1974). By contrast, much research in the auditory domain has been concerned with patterns considered *good* or appropriate within restricted contexts such as specific language or music traditions. For example, there is evidence that Western listeners' recognition of melodies is facilitated by the conformance of such melodies to principles of Western music theory (Cuddy, Cohen, & Mewhort, 1981; Cuddy, Cohen, & Miller, 1979). Jones (1981) has invoked the concept of *music prototypes*, or ideals, which embody the rules of a particular music tradition (in this case, Western tonal music) and provide a stable frame of reference for the listener. In the context of the aforementioned research and speculation, it is unclear whether enhanced processing of *good* auditory patterns simply reflects familiarity with the underlying rule system or whether there is some contribution of pattern processing predispositions of the human mind.

Music traditions, after all, do not arise in a vacuum, but presumably build upon basic features of the human auditory system and cognitive processing apparatus. This might account for a number of structural similarities across different cultures such as the functional equivalence of notes an octave apart and the use of 5 to 7 discrete scale steps per octave (Dowling & Harwood, 1986). At the same time, however, music traditions differ considerably in the construction of their scales, the nature and use of rhythmic devices, the definition of phrase completion, and higher-order organizational forms. As a result, listeners may have difficulty perceiving important distinctions from an unfamiliar music tradition just as they have difficulty parsing the speech stream of a foreign language.

Given the enormous diversity of music traditions, the task of formulating general principles of *good form* seems formidable indeed. In fact, numerous efforts to delineate music universals have failed to proceed beyond the most elementary features (Harwood, 1976), indicating, perhaps, that cross-cultural approaches may not readily yield such principles. One alternative to the cross-cultural strategy is a developmental strategy involving listeners with relatively limited exposure to *any* music tradition. The naive or infant listener relies primarily on innate pattern perception skills to decode music or other auditory input. It follows, then, that music patterns readily discerned by infants are either inherently easy to process or they embody aspects of a music tradition that are readily acquired. In this sense, they can be considered *good*, reflecting basic or universal principles of pattern processing.

Research on language development and phonological processing in particular has revealed that infants become sensitive to the phonemic categories or building blocks of their native language at approximately 1 year of age (Best & McRoberts, 1989; Best, McRoberts, & Sithole, 1988; Werker & Lalonde, 1988; Werker & Tees, 1984). Before this time, they seem to be equally sensitive to foreign speech contrasts as to those of their native language. Thus, an initially broad range of sensitivity to speech contrasts (presumably innate) is later narrowed on the basis of specific speech input.

There is suggestive but more fragmentary evidence of experiential effects in the earliest days of life. For example, neonates attend preferentially to their mother's voice over a stranger's voice (DeCasper & Fifer, 1980) and to their native language-to-be over a foreign language (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988). While the mechanisms in question have not been specified, it is likely that prosodic features are implicated (see Trehub & Trainor, in press). Indeed, there is evidence of the universal use of specific pitch contours in the highly modulated speech directed to infants (Fernald, Taeschner, Dunn, Papoušek, de Boysson-Bardies, & Fukui, 1989; Grieser & Kuhl, 1988; Papoušek & Papoušek, in press) and of demonstrable effects of such speech on infant attention and affect (Fernald, in press; Fernald & Kuhl, 1987; Werker & McLeod, 1989). The characteristic pitch contours of infant-directed speech soon become evident in the infant's own vocalizations (Delack & Fowlow, 1978; Papoušek & Papoušek, 1981), providing further confirmation of the importance of pitch configurational information in infant perception and production. Moreover, there is evidence that infants are sensitive to the prosodic cues that signal phrase and clause boundaries (Jusczyk, 1989; Kemler Nelson, Hirsh-Pasek, Jusczyk, & Wright Cassidy, 1989), increasing the likelihood that prosody guides the infant's early acquisition of syntax.

Some investigators have characterized infants' demonstrated sensitivity to prosodic cues as a precocious sensitivity to music aspects of speech (Fernald, 1984, in press; Papoušek & Papoušek, 1981). It would hardly be surprising, then, if infants were also sensitive to music aspects of nonspeech patterns. In fact, there is a growing body of evidence concerning infants' adult-like processing of music patterns (Trehub, 1985, 1987, 1989, 1990; Trehub & Trainor, in press). For example, infants are sensitive to the pitch contour of melodic patterns, that is, whether the pitch of successive notes rises, falls, or remains the same. Thus they detect changes in the contour of brief melodies (Chang & Trehub, 1977; Trehub, Bull, & Thorpe, 1984; Trehub, Thorpe, & Morrongiello, 1985, 1987) and tend to treat transpositions and same-contour transformations of a melody as equivalent to the original (Trehub et al., 1987). In some cases, they are also sensitive to melodic intervals (Cohen, Thorpe, & Trehub, 1987; Trehub et al., 1984; Trehub, Cohen, Thorpe, & Morrongiello, 1986), that is, the frequency difference between adjacent notes along a log frequency scale.

Examination of the circumstances in which infants are successful or unsuccessful at discriminating melodies with the same contour but different intervals is especially revealing. One study is of particular interest in this regard. Cohen et al. (1987) tested infants for their ability to discriminate a semitone change to the third note of three five-note melodies presented in transposition (i.e., starting at different pitch levels). One was composed of the notes of the major triad (e.g., C E G E C), another the notes of the minor triad (e.g., C Eb G Eb C), and the third, the notes of the augmented triad (C E G# E C). Note that all three melodies had a similar rise-fall configuration or contour. According to Western music theory, the major triad is a *good* and optimally stable structure, occurring frequently in Western music. Although Helmholtz (1885/1954) considered the minor triad to be more dissonant than the major, and empirical research has revealed a different hierarchy of stability for the notes of major and minor keys (Krumhansl, 1985), music theorists consider the minor triad to be as *good* or as stable as the major (Piston, 1969). The augmented triad, on the other hand, is considered very dissonant and unstable. The results of the Cohen et al. (1987) study revealed that infants were able to detect the semitone change to both the major and minor melodies but not to the augmented melody.

The major and augmented triads differ only by one semitone in the third note. It is especially interesting, then, that when the standard melody was major and the contrasting melody augmented, infants could perform the discrimination but when these were reversed (i.e., augmented melody as standard and major melody contrasting), infants performed at chance levels. Under very specific circumstances, however, infants seem to be capable of discriminating changes to the augmented melody. When Trehub et al. (1986) tested infants with the same augmented melody untransposed between standard and contrasting versions (i.e., same starting pitch level), infants were able to use absolute frequency cues to perform above chance levels.

The triadic melodies in the aforementioned studies were structurally simple, being symmetric and composed from three-note sets. It is possible, then, that infants' enhanced processing of *good* patterns is confined to extremely simple contexts such as these and is therefore of limited generality or significance. For adult listeners, we know that melodic symmetry can enhance aesthetic preference

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(Balch, 1981) and memory (Dowling, 1972) but no comparable information is available for infant listeners. In the present investigation, we sought to determine whether non-symmetric patterns composed from five distinct notes could function as *good* patterns for infant listeners. In addition, we sought to specify aspects of tonal structure that underlie infants' differential sensitivity.

According to Western music theory, each octave is divided into 12 equally spaced intervals called semitones, the notes of which form a chromatic scale. Music compositions are not based on this equal-interval chromatic scale but rather on an unequal-interval subset. If the notes of the chromatic scale are numbered from 0 to 12 (where notes 0 and 12 are one octave apart), the 7-note diatonic major scale consists of notes 0, 2, 4, 5, 7, 9, 11, and 12, where note 0 (as well as 12) defines the key and is the reference or tonic note of the scale. Diatonic major scales can be formed starting on any note so long as the intervals between notes remain the same [e.g., the notes 3, 5, 7, 8, 10, 12(0'), 14(2'), and 15(3') also form a diatonic major scale]. Scales or melodies that start on different notes but contain the same intervals are said to be transpositions of one another. Within extended pieces of music,

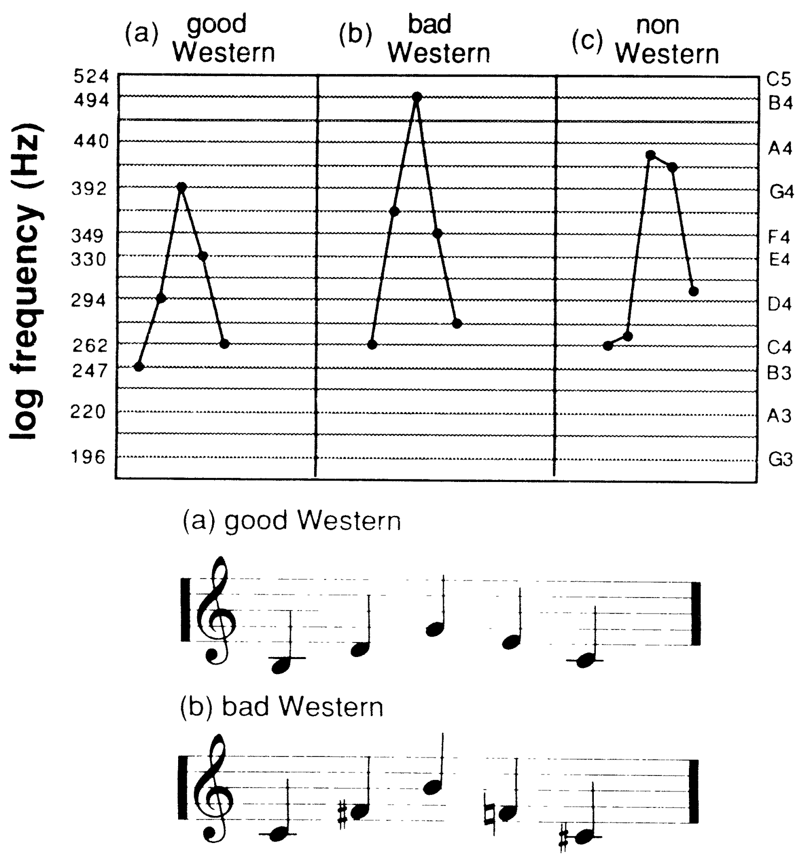

Figure 1. Upper panel: the *good* Western melody (a), *bad* Western melody (b), and non-Western melody (c), shown on a log-frequency and semitone scale. Successive horizontal lines represent notes a semitone apart; numbers associated with note names denote the relevant octave. Lower panel: the Western melodies in standard music notation. The non-Western melody cannot be presented in this format.

modulations to different keys are common, although a piece usually ends in the key in which it begins. Ornamental notes may go outside the notes of the key but not outside the underlying chromatic scale. In addition, different notes within a key are assumed to have different roles. For example, the notes of the tonic triad (0, 4, 7 in the key of 0, or C E G in C major) occur frequently and are thought to confer a sense of stability and coherence (Cuddy & Badertscher, 1987; Krumhansl, 1985; Piston, 1969). By contrast, the notes of the dominant 7th chord [7, 11, 14(2'), 17(5') in the key of 0, or G B D F in C major] are thought to be unstable, requiring resolution to the tonic triad (Piston, 1969).

To examine infants' ability to detect small changes to tone patterns as a function of music *goodness,* we created three five-note melodies, all embodying the same rise-fall contour (see Figure 1). The first (B^3 D^4 G^4 E^4 C^4 in C major) was a *good* Western melody, consisting of notes from the diatonic major scale such that a dominant triad (B^3 D^4 G^4) resolved to a tonic triad (G^4 E^4 C^4). The second was a *bad* Western melody (C^4 $F\#^4$ B^4 F^4 $C\#^4$), with notes drawn from the chromatic scale but not from any single diatonic scale. The order of notes in this melody did not exemplify Western ideas of good melodic motion in that the melody contained two tritone intervals (C^4 to $F\#^4$ and B^4 to F^4), which are considered to be particularly dissonant. The third was a *bad* non-Western melody in the sense that its set of notes was not drawn from the chromatic scale. In fact, two of its intervals were smaller than a semitone. For all three melodies, the infant's task was to detect a semitone change in the fourth position of the five-note melody.

Given the identical contour, note set size, and temporal structure (equally spaced notes) of all three melodies, any performance differences would necessarily be attributable to the internal structure of such melodies, specifically the relations among component pitches. If either symmetry or the smaller (three-note) set size of earlier research (Cohen et al., 1987) is necessary for infants' discrimination of semitone changes, then infants should fail on all of the current tasks. If these factors pose no problem and infants are also receptive to a large or unlimited range of pitch relations, then they should succeed equally on all changes. If, however, aspects of diatonic structure are congenial to infants' pattern processing dispositions, either by virtue of innate or experiential factors, then infants should perform better on the *good* melody than on the two *bad* melodies. Finally, if semitone structure in general facilitates perceptual processing, then infants should perform better on the *bad* Western than on the non-Western melody.

Method

Infants' ability to discriminate the melodic contrasts was evaluated using a conditioned head-turning task. The procedure follows closely that used by Trehub et al. (1987). The standard melody served as a repeating background, and the infant's task was to detect the occasional substitution of a contrasting melody, which incorporated a semitone drop in the pitch of the fourth tone. To eliminate absolute frequency cues, melodies were presented in five transpositions (i.e., starting on five different pitches while preserving the intervals between successive tones).

Subjects

The participants in the final sample were 30 healthy, full-term infants (15 girls, 15 boys) 7 to 10 months of age (mean age = 8.5 months). A further 12 infants were excluded for failing to complete the test session due to fussing or crying (n = 2) or failing to meet the training criterion (n = 10).

Apparatus

Testing took place inside a double-walled, sound-attenuating booth (Industrial Acoustics Co.). The experiment was controlled by a microcomputer (Commodore PET, Model 2001) and custom-built interface. Stimuli were generated on line by a synthesizer/function generator (Hewlett-Packard 3325A), with intensity controlled by a programmable attenuator (Med Associates). Tones were played through one channel of a stereo amplifier (Marantz, Model 1010) to a single loudspeaker (Avant). The computer also controlled four different mechanical toys in a four-chamber, smoked Plexiglas box under the loudspeaker as well as a button box used by the experimenter for recording responses.

Stimuli

There were three conditions in which infants were required to detect a semitone (1/12 octave) change to the fourth note of a standard 5-note melody (see Figure 1). In the *good* Western condition, the standard melody consisted of the notes $B^3 D^4 G^4 E^4 C^4$ (247, 294, 392, 330, 262 Hz), where the subscripts represent the octave from which a note is drawn (e.g., C^4 is middle C). This melody can be considered *good* because all notes belong to one key (C major) and the particular arrangement of notes implies a harmony of dominant resolving to tonic, which is characteristic of Western music. In the *bad* Western condition, the standard melody consisted of the notes $C^4 F\#^4 B^4 F^4 C\#^4$ (262, 369, 494, 349, 277 Hz). This melody is *bad* in the sense that it fails to confer a sense of key and contains two tritones (C^4 to $F\#^4$, B^4 to F^4), the tritone being the most dissonant interval, according to Western music theorists. In the *bad* non-Western condition, the standard melody consisted of the frequencies 262, 270, 427, 415, 305 Hz. These notes cannot be placed along a semitone scale and two of the intervals are smaller than a semitone (262-270, 427-415 Hz) but are, nevertheless, discriminable by infants (Olsho, 1984). The three standard melodies were similar, however, in having a simple, rising-falling contour.

The *good* melody was transposed to five different keys, which were chosen to be closely related in the music sense; these were Bb, F, C, G, and D major. The *bad* Western melody was likewise transposed to obtain a set having the starting notes $Bb^3 F^4 C^4 G^4$ and D^4. The starting notes of the five transpositions of the *bad* non-Western melody (227, 262, 305, 355, 397 Hz) were not related by semitones, but were in the same approximate range as those of the *bad* Western melody. Similar sets of contrasting melodies (i.e., with the fourth note of the above melodies lowered a semitone) were also generated to be used on change trials in each condition (see Table 1).

Table 1

Frequencies (Hz) of melodies for each condition and each key or starting tone

	Key	Starting tone	Frequencies (Hz)				
Good Western Melody							
Standard	Bb	1	220	262	349	294	233
Contrasting			220	262	349	277	233
Standard	F	2	330	392	523	440	349
Contrasting			330	392	523	415	349
Standard	C	3	247	294	392	330	262
Contrasting			247	294	392	311	262
Standard	G	4	369	440	587	494	392
Contrasting			369	440	587	466	392
Standard	D	5	277	330	440	369	294
Contrasting			277	330	440	349	294
Bad Western melody							
Standard	Bb	1	233	330	440	311	247
Contrasting			233	330	440	294	247
Standard	F	2	349	494	659	466	369
Contrasting			349	494	659	440	369
Standard	C	3	262	369	494	349	277
Contrasting			262	369	494	330	277
Standard	G	4	392	554	738	523	415
Contrasting			392	554	738	494	415
Standard	D	5	294	415	554	392	311
Contrasting			294	415	554	369	311
Bad non-Western melody							
Standard	Bb	1	227	234	370	360	264
Contrasting			227	234	370	340	264
Standard	F	2	355	366	579	562	413
Contrasting			355	366	579	531	413
Standard	C	3	262	270	427	415	305
Contrasting			262	270	427	392	305
Standard	G	4	397	409	647	629	462
Contrasting			397	409	647	594	462
Standard	D	5	305	314	497	483	355
Contrasting			305	314	497	456	355

In each condition, the repeating background consisted of a quasi-random series of tokens of the standard set, with the sequence determined such that each change of key (or starting tone for *bad* melodies) was always made to one of the near music keys, and the same key (or starting tone) was never used consecutively. In other words, key changes in the background were a random walk through the set Bb, F, C, G, D. A randomized block of 100 exemplars was generated prior to testing, and was recycled as necessary to achieve a continuously repeating variable background for both the training and test phases of the session. On any particular change trial, the contrasting melody was presented in the key (or starting tone) designated for the background melody it replaced. Thus, the key changes between background and contrasting melodies obeyed the same constraints as those between successive background melodies.

All tones were 200 ms in duration with linear rise and decay times of 30 ms. Intertone silences were 200 ms and melodies were separated by 1400 ms. Average intensity level was 75 dBA and ambient noise level (measured at the approximate location of infant's head) was 27 dBA (42 dBC).

Procedure

Infants were tested individually in a between-subjects design. Each infant was seated on the parent's lap facing the experimenter, with the loudspeaker and toy box located 45° to the infant's left. The experimenter and parent listened to music through headphones, which served to mask the stimuli and prevent inadvertent cues for the infant.

The transpositions of the standard melody repeated continuously, forming a background against which the infant had to detect the target changes. When the infant was quiet and facing directly ahead, the experimenter signalled to the computer (via the button box) to begin a trial. A test trial consisted of either two presentations of the contrasting melody (change trial) or two presentations of the standard melody (no-change or control trial). Successive melodies always differed in key (i.e., starting pitch level); this was true for contrasting as well as background melodies. Over the course of the test session, there were 15 no-change (control) trials and 15 change trials (the fourth note of the standard melody lowered by a semitone). The experimenter pressed a button (i.e., signalled to the computer) whenever the infant made a head turn 45° or more to the left. The response interval (i.e., period in which the infant could be reinforced for head turns to a sound change) began with the onset of the first potentially changed note (i.e., the fourth note of the first presentation of the five-note pattern) and ended 5 s later, before the onset of the subsequent background melody. If, on a change trial, the infant turned 45° toward the loudspeaker during the response interval, the computer illuminated and activated one of the mechanical toys. Head turns at other times were not reinforced. The computer recorded the presence or absence of a head turn during each change and no-change (control) trial.

Before beginning the 30-trial test phase, infants participated in a training phase in which only change trials were presented and these incorporated a larger interval change (i.e., the fourth note lowered by three semitones) compared to that of the test phase (i.e., single semitone change). Initially, the contrasting melody was presented at a level 5 dB greater than the standard melody to draw infants' attention to it. If the infant failed to respond on two consecutive training trials, the intensity of the contrasting melody was increased by 5 dB. If infants responded correctly to two consecutive training trials, the intensity of the contrasting melody was lowered by 5 dB until the intensity was equivalent to that of the standard melody. Infants were required to achieve 4 successive correct responses (within 20 training trials) with the contrasting melody at the same level as the background melody before proceeding to the test phase.

Results

The data consisted of the number of change trials and no-change trials on which a head turn was observed. The mean proportions of head turns on change trials and on no-change trials are shown in Figure 2. The data analysis followed that of Thorpe, Trehub, Morrongiello, and Bull (1988), who employed the data handling techniques of signal detection theory. The raw data were transformed to *d'* (d prime) to obtain a single score for each infant that would be consistent with conventional

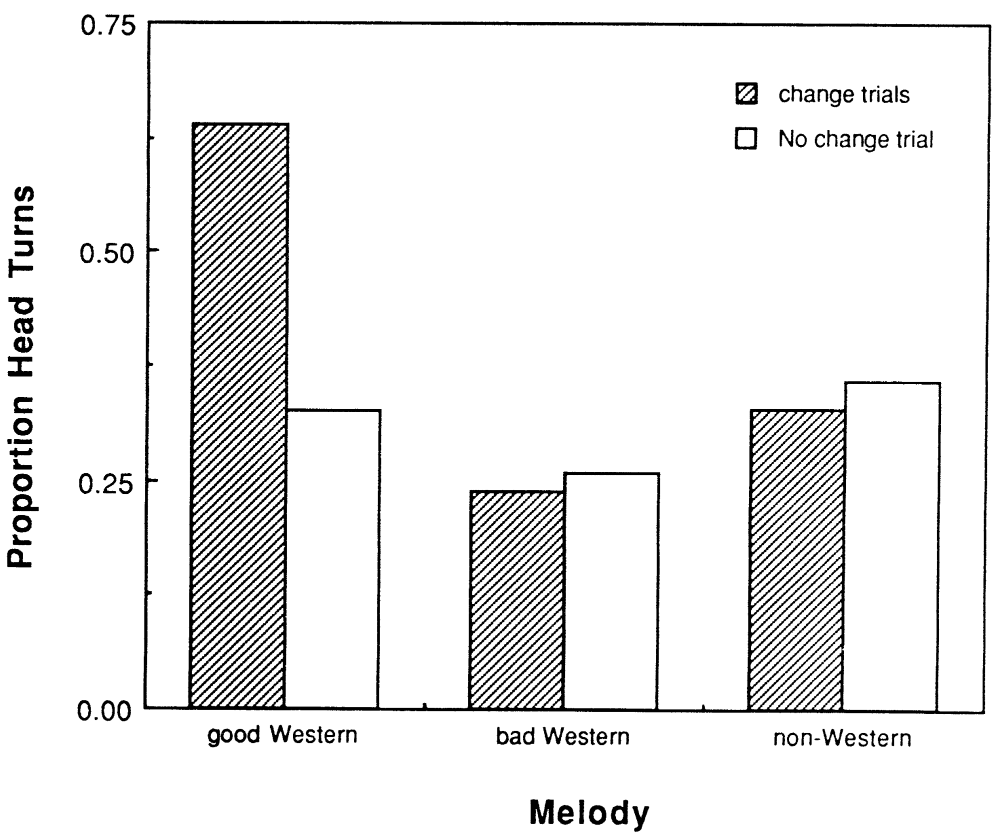

Figure 2. Average proportion of head turns on change trials and no-change (control) trials for each melody.

assumptions regarding the independence of trials and the underlying distribution of scores. The transformation also removed the effects of response bias. Tables for the adult *yes/no* task were used (Swets, 1964); the proportion of turns on change trials was used to estimate the probability of a hit and that on no-change trials the probability of a false alarm. The *d'* scores were assumed to be normally distributed (see Green & Swets, 1966) and were analyzed using Student's comparisons and analysis of variance.

Because of the small number of trials per subject, the occasional score of 0 or 15 out of 15 (which transforms into an infinite *d'* score), was considered to reflect a statistically rather than a truly infinite *d'* (see Macmillan & Kaplan, 1985). (There was one such score in the present data set.) To avoid the complications of infinite *d'*s, the proportions of responses on each type of trial were computed following Thorpe et al. (1988). Hence, proportions were calculated by adding 1/2 to the number of responses by each infant on each type of trial, and dividing the resulting score by the number of trials plus 1. This modification of the *d'* transformation has a very small effect on the distribution of scores, but maintains the rank order of performance among subjects and treats the data from each subject equivalently. [See Thorpe et al. (1988) and Thorpe (1985) for a more detailed discussion of the application of the *d'* transformation to conditioned head-turning data.]

The mean *d'* score for the *good* Western condition was 0.79 ($SD = 0.40$). A one-tailed *t*-test showed that this was significantly greater than zero, $t(9) = 6.18$, $p < .0002$, indicating discrimination of a semitone change to the fourth note of this well-structured pattern. (A one-tailed *t*-test is appropriate since a mean *d'* significantly less than zero is not meaningfully different from the null hypothesis.) By contrast, infants failed to detect the semitone change in the two other conditions, the *bad* Western melody [mean $d' = -0.05$, $SD = 0.47$, $t(9) = 0.36$] or the *bad* non-Western melody [mean $d' = -0.09$, $SD = 0.38$, $t(9) = -0.72$]. A one-way analysis of variance revealed a significant effect of condition, $F(2,27) = 13.91$, $p < .0001$, and a Newman-Keuls comparison of ordered means indicated significant differences between performance on the *good* melody and either *bad* melody but not between the two *bad* melodies. Interestingly, all 10 infants who were eliminated for failing to meet the training criterion and one out of the two who were excluded for crying or fussing heard either the *bad* Western melody or the *bad* non-Western melody.

Discussion

Infants were successful at discriminating a semitone change in a well-structured Western melody but not in a poorly-structured Western melody or a non-Western melody. Previous findings of enhanced processing for *good* Western melodies had involved symmetrical melodies composed from three-note sets (Cohen et al., 1987). The melodic asymmetry and larger note set of the current study confirm that symmetry and minimal set size (three notes) are not essential properties of a *good* melody for infant listeners. What is notable, however, is that one of the

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good melodies used by Cohen et al. (1987) and the *good* melody of the current study are similar in another respect, both being based on major triads. The other *good* melody used by Cohen et al. (1987) was based on the minor triad.

Major and minor triads have a number of interesting features, in addition to their centrality to Western tonal structure. The notes of the major triad form intervals approximating extremely simple frequency ratios (4:5:6), with those of the minor triad involving relatively simple ratios (10:12:15). By contrast, the augmented triad has more complex interval ratios (16:20:25). Balzano (1982) has used group theory to demonstrate that diatonic structure exhibits interesting mathematical properties, with the major and minor triads forming optimally compact schemes. It is also of interest that the outside notes of both the major and minor triads form the interval of the perfect fifth, an interval that occurs frequently in natural sounds (e.g., the formant structure of vowels).

The present findings indicate that patterns based on major or minor triads may be more readily encoded by infant listeners. The developmental importance of major and minor triads is not borne out cross-culturally in music, where neither triad enjoys universal application. What is relatively common, however, is the interval of the fifth, increasing the possibility that this interval underlies the observed enhancement in perceptual processing.

It is also possible that relatively little exposure to diatonically structured music is necessary for enhanced processing of such music material. Thus, unsystematic exposure to maternal singing or commercial jingles may result in the internalization of music prototypes or ideals (Jones, 1981) that facilitate the processing of melodies based on diatonic scales as opposed to chromatic or other scales. If experiential factors are implicated, then Western infants should perform poorly on *good* foreign melodies with non-Western scale structures, as is the case for adults (Castellano, Bharucha, & Krumhansl, 1984). If, on the other hand, infants perform well on *good* melodies from other music cultures, then common features of *good* Western and non-Western melodies could perhaps be identified. In the visual domain, infants can categorize *good* patterns as early as 3 months of age, *intermediate* patterns by 5 months of age, and *poor* patterns by 7 months of age (Younger & Gotlieb, 1988), when *goodness* is defined by Garner's (1970) translation of Gestalt principles into information theoretic terms. In the auditory domain, the specification of factors underlying infants' definition of *good* melodies and the progressive elaboration of this definition over childhood poses important challenges for future research.

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