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What Mediates Infants' and Adults' Superior Processing of the Major Over the Augmented Triad?

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In this paper, the claim that the major triad has special status for infant as well as adult listeners is evaluated. In Experiment 1, infants and adults were required to detect a downward semitone change in a five-note melody based on the major triad and in another five-note melody based on the augmented triad. Both infants and adults performed significantly better on the major triad melody. In Experiment 2, infants and adults were evaluated on their detection of a downward semitone change in a five-note melody that incorporated a perfect fifth or augmented fifth relation but that also contained non-Western intervals. Again, infants and adults performed significantly better on the melody that incorporated the perfect fifth relation. These findings imply that enhanced processing of perfect fifth relations may account for infants' and adults' effective processing of the major triad.

ADULTS in our culture are sensitive to diatonic structure in music (for a review see Krumhansl, 1990), processing diatonic melodies more easily than nondiatonic melodies (e.g., Cuddy, Cohen, & Mewhort, 1981; Deutsch, 1982, 1986; Dowling & Harwood, 1986). This finding is presumed to reflect music processing schemas specific to diatonic structure. Moreover, such schemas are presumed to result from years of exposure to Western music. On the other hand, certain aspects of music processing most likely reflect innate properties of the auditory system. For example, even very young infants perceive the equivalence of notes an octave apart (Demany & Armand, 1984). At present, however, there is little specification of which aspects of Western music processing depend on basic auditory mechanisms and which require extensive exposure to Western tonal music. Infants' sensitivity to musical features most likely arises from basic auditory mechanisms rather than acquired music processing skills. Thus, comparisons of infant and adult listeners could reveal features of Western music structure that are readily processed with no exposure or minimal

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exposure. Such features would be reasonable candidates for universal or near-universal features in music.

Experiment 1

In the present experiment, we compared infants' and adults' ability to detect semitone changes in typical and atypical melodic forms in Western music, the typical form being the major triad, and the atypical form, the augmented triad. The major triad is formed by the first, third, and fifth notes of the Western major scale. The first and third notes are separated by four semitones and the third and fifth notes by three semitones. According to Western music theory, the major triad is the most perceptually stable and consonant structure (Pierce, 1983; Piston, 1969; Schenker, 1954). Moreover, the major triad chord occurs more frequently than any other chord across a variety of Western musical styles (Cohen, Thorpe, & Trehub, 1987; Roberts, 1982). The augmented triad is superficially similar to the major, differing only in its final note, which is raised by a semitone. Thus, the component notes of the augmented triad are separated by four and four semitones rather than four and three, as in the major triad. The augmented triad is a relatively uncommon musical form because it cannot be generated from any subset of three notes from the major scale. Moreover, music theorists (e.g., Piston, 1969) consider the augmented triad to be perceptually dissonant and unstable, requiring resolution.

Empirical research has confirmed the special role of the major triad for Western listeners (Krumhansl, 1990; Roberts & Shaw, 1984). For example, adult listeners rate the first, third, and fifth notes of the major scale (which together form a major triad) as fitting best into the melodic context of the major scale (Krumhansl & Shepard, 1979). Moreover, they rate the major chord following the augmented as sounding better than the augmented chord following the major (Krumhansl, Bharucha, & Kessler, 1982), an asymmetry that is presumed to reflect the greater stability of the major over the augmented chord.

Although the special status of the major triad may arise from listeners' extended exposure to Western music, there is reason to believe otherwise. Trehub, Cohen, Thorpe, and Morrongiello (1986) evaluated infants' ability to detect an upward semitone change in one note of two five-note melodies, one melody based on the major triad (notes C_4 E_4 G_4 E_4 C_4; frequencies 261, 329, 391, 329, 261 Hz) and the other on the augmented triad (notes C_4 E_4 $G\sharp_4$ E_4 C_4; frequencies 261, 329, 415, 329, 261 Hz). Infants were able to detect the semitone change in both melodies. Because Trehub et al. (1986) presented the standard and comparison melodies at a single pitch level (i.e., untransposed), they made it possible for infants to rely on absolute-frequency cues rather than relative-frequency (interval) cues, potentially obscuring differences in discriminability between the major- and augmented-triad melodies.

Cohen et al. (1987) subsequently presented the same major- and augmented-triad melodies in transposition, eliminating such absolute-frequency cues. Infants' task was to detect a semitone change upward to the third note of the major-triad melody and a semitone change downward to the third note of the augmented-triad melody. Because the major and augmented triads differ only by a semitone in the third note, the change in the major-triad melody resulted in the augmented-triad melody and the change in the augmented-triad melody resulted in the major-triad melody. In fact, infants were able to discriminate the semitone change only when the major-triad melody was the standard melody. This asymmetry provides suggestive evidence that, for infants, the major triad provides a better context than the augmented for the detection of subtle interval changes. However, unequivocal interpretation of these findings is precluded by the possibility that infants find upward changes that extend the frequency range more noticeable than downward changes that remain within the frequency range (Trehub, Morrongiello, & Thorpe, 1985). Indeed, Trainor and Trehub (1993) demonstrated that infants were able to detect an upward, range-extending semitone change to the augmented triad presented in transposition. Accordingly, we explored the special status of the major triad by evaluating infants' and adults' ability to detect downward semitone changes (within the frequency range) to the major and augmented triads presented in transposition.

METHOD

Subjects

The 20 infant participants (8 female, 12 male) were 9–11 months old (average, 10 months, 5 days). All were healthy, born at term, and free of colds on the day of testing. Three other infants did not complete the test session because of crying or fussing. The 20 adult participants (10 female, 10 male) were 19–35 years old (mean, 22 years). Listeners reported 0–13 years of music lessons (mean, 3 years). Five other adults were excluded from the sample because of their failure to meet the training criterion (see Procedure).

Apparatus

Tones were generated by two Hewlett-Packard 3325A synthesizer/function generators, attenuated by two Med Associates attenuators, and turned on and off by two Med Associates rise/fall switches. The stimuli were subsequently fed through a Marantz 1070 stereo amplifer to a single Avant 2AX loudspeaker located in a double-walled, sound-attenuating booth (Industrial Acoustics Co.). An ECS microcomputer controlled the procedure and equiment (synthesizer/function generators, attenuators, rise/fall switches, reinforcers) through a custom-made interface. The infant or adult subject sat facing the experimenter (the infant on parent's lap), with the loudspeaker to the left. The experimenter signaled to the computer via a touch-sensitive box (out of view) when the subject was ready for a trial (i.e., quiet and looking directly ahead) and when the subject responded (45° or greater left head turn for infants, hand raise for adults). Four lights and mechanical toys for rewarding correct responding were housed in a four-chamber box with a smoked Plexiglas front that was located under the loudspeaker. The parent and experimenter listened to masking music through headphones attached to an independent tape deck.

Stimuli

There were two different conditions (10 infants, 10 adults per condition), one with the major-triad and the other with the augmented-triad melody used by Cohen et al. (1987) and Trehub et al. (1986) (see Figure 1). Because these melodies differ in the relationship between their highest and lowest notes, that is, a perfect fifth (seven semitones) for the major-triad and an augmented fifth (eight semitones) for the augmented-triad melody, they were designated as the Maj-P5 (i.e., major triad with perfect fifth relation) and Aug-Aug5 (i.e., augmented triad with augmented fifth relation), respectively. Successive melodies were separated by 1200 ms and presented in transposition (i.e., different pitch levels) to closely related keys, that is, with starting notes a perfect fifth (seven semitones) or perfect fourth (five semitones) apart. (With octave equivalence, fourths and fifths in opposite directions are equivalent.) The starting notes (or keys) of successive melodies were chosen randomly from the set B♭, F, C, G, and D (233, 349, 261, 391, 293 Hz) such that the above constraint was met.

In the key of C major, the standard Maj-P5 melody consisted of the notes C_4 E_4 G_4 E_4 C_4 (frequencies: 261, 329, 391, 329, 261 Hz). The comparison melody differed from the standard in that the third note was lowered by a semitone (G_4, 391 Hz became F♯, 369 Hz). Moreover, the comparison melody was always presented at a different pitch level (i.e., transposed) relative to the immediately preceding standard melody. The standard Aug-Aug5 melody in the key of C major consisted of the notes C_4 E_4 $G\sharp_4$ E_4 C_4 (frequencies 261, 329, 415, 329, 261 Hz). The comparison melody differed by having the third note lowered by a semitone ($G\sharp_4$, 415 Hz became G_4, 391 Hz; see Figure 1) and was also presented in transposition. The notes of each melody were contiguous and 400 ms in duration with 10-ms rise and decay times.

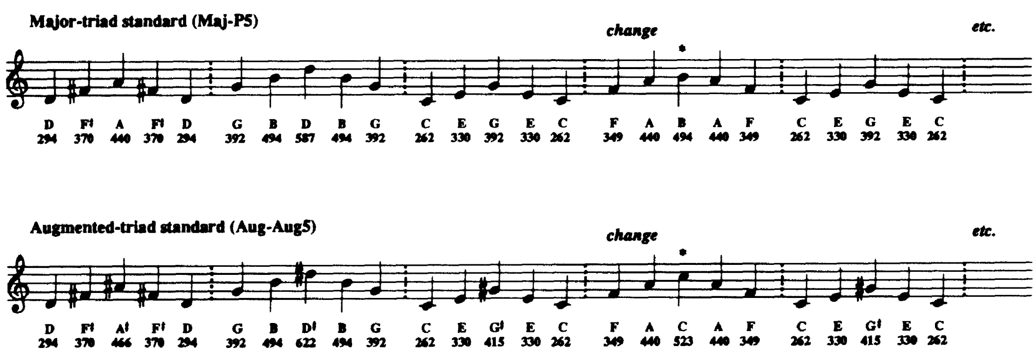

Fig. 1. Upper panel: The standard major-triad melody (Maj-P5) is repeated three times (in transposition), followed by a change in the third note of the melody (indicated by asterisk, fourth repetition) and a subsequent return to the standard melody (fifth repetition). Lower panel: A comparable sequence with the augmented-triad melody (Aug-Aug5) as standard.

In the training phase (see *Procedure*), the standard melody repeated as in the test phase, but the change to be detected was much larger. Specifically, the third note was raised six semitones for the first three training trials (Maj-P5 melody: G_4, 391 Hz, became $C\sharp_5$, 554 Hz; Aug-Aug5 melody: $G\sharp_4$, 415 Hz, became D_5, 596 Hz) and three semitones for the remaining training trials (G_4, 391 Hz became $B\flat_4$, 446 Hz; $G\sharp_4$, 415 Hz became B_4, 493 Hz).

Procedure

The standard or background melody (Maj-P5 or Aug-Aug5) was repeated with intermelody intervals of 1200 ms throughout the entire test session. Repetitions were in transposition, that is, each repetition was at a different pitch level from the previous repetition. The subject's task was to detect a relative pitch (i.e., interval) change in the repeating melody that occurred on change trials (see Figure 1). The experimenter signaled, via a button on the touch-sensitive box, the subject's apparent readiness for a trial (quiet, facing directly ahead). This procedure resulted in a variable number of repetitions of the standard background melody between trials, the minimum number of such repetitions being two. Half the trials were change trials, in which one note of the melody was altered. The other half were control (no change) trials in which the standard melody repeated without change. The experimenter signaled the occurrence of a response (infants turning 45° or more to the left, adults raising their hand) via another button on the touch-sensitive box. On change trials, responses within 3 s (beginning with the changed or third note) resulted in the automatic illumination and activation of an animated toy for 4 s. On control trials, responses within 3 s (beginning with the unchanged third note) were recorded but were not reinforced. The experimenter (and parent in the case of infant subjects) listened to masking music over headphones, so they were unaware of the type of trial being presented. Each subject completed 30 trials, 15 change and 15 control.

The test phase was preceded by a training phase to familiarize subjects with the contingency between responding to changes and reinforcement. As in the test phase, the standard background melody repeated in transposition. In contrast to the test phase, however, no control trials were presented during the training phase. In any case, control trials and background repetitions were indistinguishable from the listener's perspective. During training, failure to respond on two successive change trials resulted in the next change melody being presented at a level 5 dB greater than the repeating background melodies. Correct responding resulted in a 5-dB decrease in the intensity of the next change melody, until the background intensity level was reached. Subjects were required to make four successive correct responses at equivalent background and change intensity within 20 trials.

RESULTS AND DISCUSSION

To eliminate response bias (see Thorpe, Trehub, Morrongiello, & Bull, 1988), the proportions of head turns on change trials (hits) and on control trials (false alarms) were transformed to d' scores for each subject according to yes/no signal detection tables (Swets, 1964). Proportions of 0 or 1 translate into infinite d' scores, but such scores in the present experiment (only a few occurred) most likely resulted from the small number of trials per subject (i.e., sampling error) (see Macmillan & Kaplan, 1985). Thus, proportions were transformed by adding ½ to the number of responses (out of 15) and dividing by the number of trials plus 1 (i.e., 16). This transformation maintains the original order of d' scores and has a minimal effect on actual d' values (see Thorpe et al., 1988).

Both infants and adults performed significantly better on the downward semitone change in the top note of the Maj-P5 than on the comparable change in the Aug-Aug5 melody, $t(18) = 6.39$, $p < .001$ for infants, $t(18) = 4.51$, $p < .001$ for adults (see Figure 2; Table 1). Furthermore, infants performed significantly above chance levels on the Maj-P5 melody, mean $d' = .89$, $t(9) = 6.54$, $p < .001$, but not on the Aug-Aug5 melody, mean $d' = -.28$. Adults showed the same pattern of performance, mean $d' = 2.58$, $t(9) = 7.47$, $p < .001$ for the Maj-P5 melody, and mean $d' = .31$, $t(9) = .84$, n.s., for the Aug-Aug5 melody. Number of years of music lessons was uncorrelated with adult performance on both conditions.

These results confirm previous findings of superior infant performance for the major triad compared with the augmented (Cohen et al., 1987), indicating that this effect also occurs in the context of downward changes that do not extend the frequency range. Furthermore, the relative difficulty of conditions was remarkably similar for infant and adult listeners, both groups being unable to detect the semitone change in the augmented triad.

The processing superiority for the major triad in infant as well as adult listeners is most likely attributable to fundamental auditory processes. Nevertheless, the specific aspects of the major triad that are responsible for this effect remain to be determined. Perhaps the most obvious difference between major and augmented triads is that the outer notes of the major triad (first and third notes of the Maj-P5 melody) form a perfect fifth interval, which consists of a very simple frequency ratio relation (2:3), in contrast to the outer notes of the augmented triad, which form a

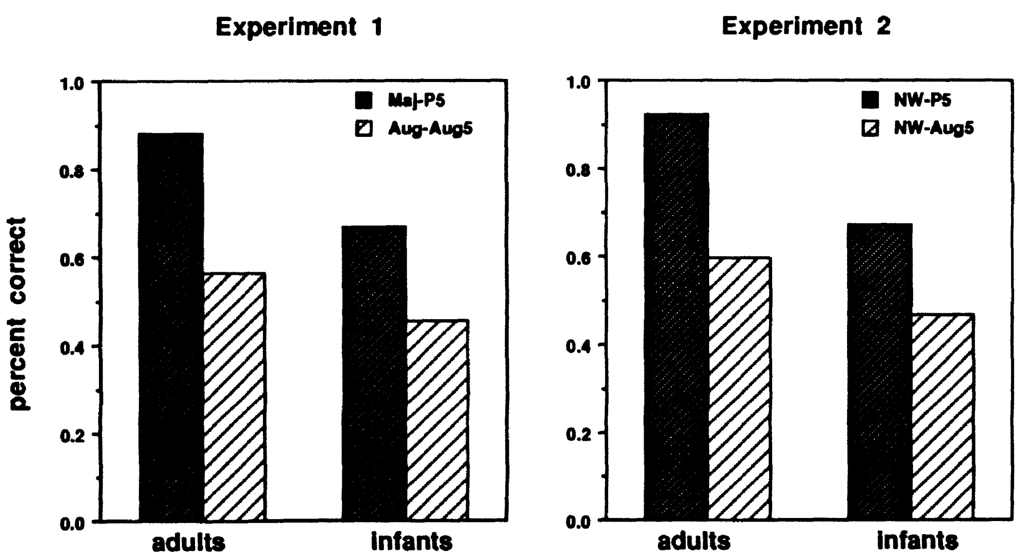

Fig. 2. Percent correct performance for infants and adults in Experiments 1 and 2.

TABLE 1
d' Scores in Experiments 1 and 2

	Experiment 1		Experiment 2	
	Maj-P5	Aug-Aug5	NW-P5	NW-Aug5
Infants				
Mean	0.89	−0.28	0.95	−0.23
SD	0.43	0.38	0.51	0.41
Adults				
Mean	2.58	0.31	2.98	0.67
SD	1.09	1.16	0.84	0.85

more complex frequency ratio (5:8). If all three notes of the triad are considered, the frequency ratios of the major triad (4:5:6) are considerably simpler than those of the augmented triad (20:25:32). In Experiment 2, we explored the perception of the perfect fifth relation in the context of a triad with more complex frequency ratios overall.

Experiment 2

To separate perfect and augmented fifth relations from major and augmented fifth triads, artificial non-Western triads were used. Specifically, the standard melodies of Experiment 1 were altered by lowering the second and fourth notes (which were identical) by half a semitone (i.e., a quarter of a tone), a difference that is discriminable by infants in some melodic contexts (Lynch, Eilers, Oller, & Urbano, 1990). This change resulted in melodies with the same outer notes as the major and augmented triads but with intervals not found in Western diatonic structure. The standard melodies were designated NW-P5 and NW-Aug5 (i.e., non-Western triad with perfect fifth or augmented fifth interval). Again, the task was to detect a downward semitone change in the top (third) note of each melody. If exposure to the major triad in Western music accounted for superior performance on the major triad melody in Cohen et al. (1987) and in Experiment 1 of the present report, then poor performance would be expected on both the non-Western melody with perfect fifth relations and the non-Western melody with augmented-fifth relations. If simple frequency relations among the component notes of the major triad (4:5:6) accounted for performance, then poorer performance would be expected in the context of the more complex ratio relations of the present experiment. Alternatively, if the perfect fifth interval is intrinsically easier to process than the augmented fifth, regardless of context, then results comparable to those of Experiment 1 would be expected.

METHOD

Subjects

The 20 infant participants (12 female, 8 male) were 9–11 months old (average, 10 months, 1 day). All were healthy, born at term, and free of colds on the day of testing. Three other infants did not complete the test session because of crying or fussing. The 20 adult participants (16 female, 5 male) were 18–24 years old (mean, 20 years) and reported 0–10 years of music lessons (mean, 3.8 years). Nine other adults did not meet the training criterion (three in the NW-P5 and six in the NW-Aug5 condition).

Stimuli

There were two different conditions (10 infants, 10 adults per condition), one with the NW-P5 and the other with the NW-Aug5 melody as background pattern. The NW-P5 melody (non-Western with perfect fifth relation) was identical to the Maj-P5 melody and the NW-Aug5 melody (non-Western with augmented fifth relation) was identical to the Aug-Aug5 melody except that the second and fourth notes were a quarter tone lower in both cases. The resulting melodies had intervals not found in Western music. Note and intermelody durations as well as transpositional relations were identical to those of Experiment 1. Thus, melodies began on 233, 349, 261, 391, or 293 Hz, and immediately preceding or succeeding melodies began on notes adjacent on this list. The standard Maj-P5 melody that began on 261 Hz consisted of the frequencies 261, 319, 391, 319, and 261 Hz. The comparison melody had the third note lowered by a semitone (391 Hz became 369 Hz) and was always presented at a different pitch level than the preceding standard melody. The standard Aug-Aug5 melody beginning on 261 Hz consisted of the frequencies 261, 319, 415, 319, and 261 Hz. The comparison melody was always transposed and had the third note lowered by a semitone (415 Hz became 391 Hz). As in Experiment 1, the change to be detected in the training phase was six semitones for the first three training trials and three semitones for the remaining training trials.

Apparatus and Procedure

The *apparatus* and *procedure* were identical to those of Experiment 1.

RESULTS AND DISCUSSION

The proportions of head turns on change trials (hits) and on control trials (false alarms) were transformed to d' scores for each subject, as in Experiment 1. Both infants and adults performed significantly better on the downward semitone change in the top note of the NW-P5 than the NW-Aug5 melody, $t(18) = 5.65$, $p < .001$ for infants, $t(18) = 6.10$, $p < .001$ for adults (see Figure 2; Table 1). Further, infants performed significantly above chance on the NW-P5 melody, mean $d' = .95$, $t(9) = 5.88$ $p < .001$, but not on the NW-Aug5 melody, mean $d' = -.23$. Adults showed a similar pattern of performance although they exceeded chance levels on both conditions, mean $d' = 2.98$, $t(9) = 7.49$, $p < .001$ for the Maj-P5 melody and mean $d' = .67$, $t(9) = 2.50$, $p < .05$, for the Aug-

Aug5 melody. Further, the number of years of music lessons was uncorrelated with adult performance on both conditions.

Separate two-factor ANOVAs were performed for infants and adults on the combined data of Experiments 1 and 2. The first factor was the presence of the perfect fifth or augmented fifth relation (i.e., Maj-P5 and NW-P5 versus Aug-Aug5 and NW-Aug5) and the second was the presence of Western or non-Western intervals (i.e., Maj-P5 and Aug-Aug5 versus NW-P5 and NW-Aug5). For both infants and adults, there was a main effect of the major versus augmented fifth relation, $F(1,36) = 13.69$, $p < .0001$ for infants, and $F(1,36) = 52.49$, $p < .0001$ for adults, no effect of Western or non-Western intervals, and there were no interactions.

In short, the presence of non-Western intervals had little effect on performance. Infants as well as adults found it considerably easier to detect changes in the melody with perfect fifth relations than in the one with augmented fifth relations, regardless of the context in which these relations occurred. This finding adds weight to the contention that the perfect fifth relation has special properties that facilitate its encoding and retention by human listeners (Trainor, 1991; Trehub & Trainor, 1993).

General Discussion

In Experiment 1, we demonstrated that infants and adults more easily detect a change in the top note of the major triad than of the augmented triad even when the change does not extend the frequency range of the melody. In Experiment 2, infants and adults were better at detecting a change in a melody with perfect fifth relations than in one with augmented fifth relations even when the melodic context had non-Western intervals. Because the notes related by the perfect fifth interval were not adjacent, our findings indicate that temporally separated notes can provide intrinsic structure or anchor points for melodies. Such an anchoring effect is also evident in the processing of relationships between melodies. Specifically, infants find it easier to compare melodies transposed to keys a perfect fifth apart (i.e., near keys) than those transposed to keys a major third apart (i.e., far keys; Trainor & Trehub, 1993).

Infants and adults showed remarkably similar patterns of performance on all tasks in the present study, in contrast to some previous findings of substantial adult-infant differences. For example, adults exhibit superior processing for melodies based on the Western major than on the Javanese scale, but infants perform equivalently on both (Lynch et al., 1990). Similarly, adults more readily detect melodic changes that go outside the key of a melody than those that remain within the key, but infants perform equivalently on both (Trainor & Trehub, 1992). Infants' failure to show enhanced performance for Western over Javanese melodies (Lynch et al., 1990) and better detection of out-of-key than in-key changes (Trainor & Trehub, 1992) implies that they lack adultlike knowledge of Western major scale structure. Nevertheless, the results of the present study reveal that infants are adultlike in their more efficient processing of the perfect fifth relation compared with the augmented fifth relation. Although adults' performance could arise from extensive exposure to Western music, infants have not had much exposure nor do they process melodies in terms of major scale structure. A more parsimonious explanation for the present findings and those of Cohen et al. (1987) and Trainor and Trehub (1993) is that the perfect fifth is intrinsically easier to encode and retain than is the augmented fifth relation. Even if infants' limited exposure to Western music is presumed to have some effect, then, at the very least, effective processing of perfect fifth relations is easily acquired.

From an evolutionary perspective, it would be reasonable for musical systems to capitalize on fundamental characteristics of the auditory system. Sensitivity to perfect fifth relations could be one such characteristic. The perfect fifth interval features prominently in the overtone series and is therefore found in many naturally occurring sounds such as vowels. Fine-tuning to culture-specific characteristics would emerge progressively after sufficient exposure to a particular system. Enhanced processing of Western compared with Javanese melodies (e.g., Lynch et al., 1990) would be an example of such fine-tuning.

There is further evidence of special perceptual status for the perfect fifth interval. Kolinski (1967) has described the cross-cultural prevalence of singing in parallel fourths and fifth as well as octaves. (As noted earlier, fourths and fifths in opposite directions are equivalent.) He claims, moreoever, that fourths and fifths are structurally important in so-called *tribal* as well as Western music. Such cross-cultural evidence points to the perfect fifth relation as an inherently good structural basis for melodic processing.

What additional evidence would be necessary to bolster the claim, tentatively advanced here, that the perfect fifth relation is a *natural* or *primitive* processing anchor in melody perception? First, the perfect fifth should enhance processing in a variety of musical contexts, especially for listeners who are naive either by virtue of their tender age or by their predominant exposure to foreign musical systems. Second, various melodic perception and production tasks involving perfect fifth relations should be acquired more rapidly than those involving other intervallic relations. Third, we must go beyond Kolinski's (1967) anecdotal accounts to specify the incidence of perfect fifths or *perceptually equivalent* musical relations across cultures. Finally, we must distinguish between processing advantages arising from small frequency ratios in general

(Burns & Ward, 1982; Jones, 1990) and from the perfect fifth relation in particular (2:3 frequency ratio). Favorable evidence for the perfect fifth on most, if not all, counts would justify its designation as a *natural prototype* (Trehub & Unyk, 1992), analogous to the prototypes identified by Rosch (1975) in the visual domain and to the biologically determined processing biases that underlie Jones' (1990) *ideal prototypes* in music.[1]

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