Research Report

INNATENESS, EXPERIENCE, AND MUSIC PERCEPTION

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Abstract—*Musical acculturation from infancy to adulthood was studied by testing the abilities of Western 6-month-olds and adults to notice mistunings in melodies based on native Western major, native Western minor, and non-native Javanese pelog scales. Results indicated that infants were similarly able to perceive native and non-native scales. Adults, however, were generally better perceivers of native than non-native scales. These findings suggest that infants are born with an equipotentiality for the perception of scales from a variety of cultures and that subsequent culturally specific experience substantially influences music perception.*

Speech and music are complex acoustic systems that have both universal and idiosyncratic features. In speech, the consonant/vowel distinction is a universal feature of phonological systems (Jakobson, 1968). A universal feature of music is the scale, a set of frequency relationships usually formalized as a series of notes with successively higher fundamental frequencies (Dowling & Harwood, 1986; Hulse & Page, 1988; Nettl, 1956). Although consonants/vowels and scales are widely present in languages and musics of the world, different languages select different consonants and vowels, and different cultures select different specific frequency relationships (intervals) for their scales. In other words, universal components of speech and music have culturally-specific characteristics.

Although speech and music share this broad structural similarity, the development of culturally specific knowledge for universal components of speech and of music have not received comparable attention in research. The development of speech perception has been widely studied (Aslin & Pisoni, 1980; Eilers & Oller, 1988), while the development of music perception has received comparatively little attention (Dowling, 1982; Dowling & Harwood, 1986; Pick, 1979). Although certain perceptual abilities possessed by infants for music have been successfully investigated (Trehub, 1987), no previous developmental studies of the effects of culturally specific experience on music perception from infancy to adulthood have been conducted, perhaps because of the difficulties involved in obtaining comparable stimuli for and using comparable procedures with infants and older subjects.

The present study employed an operant head-turn procedure (Eilers, Wilson, & Moore, 1977), which is amenable to use with both infants and adults, to study musical acculturation by testing subjects in the perception of native and non-native musical scales. Use of this procedure allowed for investigation of musical acculturation because better perception of native than non-native scales would indicate a significant influence of the musical culture on perception. Additionally, examination of infants' performance allowed for exploration of the possibility that certain scales may be inherently easier to process than others. Adults with different levels of musical background were tested to investigate potentially complex effects of experience.

METHOD

Subjects

Fifty Western (American) subjects participated in this study. Twenty infants (mean age = 6.5 months, *SD* = 21 days), 10 musically inexperienced (M−) adults, 10 amateur musicians (M), and 10 professional musicians (M+) were tested in perception of computer-generated melodies based on native Western scales and a non-native Javanese scale. All of the subjects were screened for exposure to non-Western music through personal or parent interview, and those with any such exposure were excluded from the study.

Stimuli

Seven-note melodies based on the Western major and minor scales and the Javanese pelog scale (Kunst, 1973) were constructed (Table 1). The frequency relationships among the notes of the Western scales were based on the semitone (1.0595 ratio, 12th root of 2). In contrast, the pelog scale contained many intervals which were larger than, smaller than, and approximations of Western intervals. Individual tones were 300 ms (milliseconds) in length including 20 ms each of linear attack and linear decay. Each note contained the fundamental frequency and the second harmonic an octave above. An IBM PS2 microcomputer generated digital representations of F0 and H2 (amplitude ratio of 7:3), which were summed and then processed by a digital-analog converter. The amplifier (Accuphase E202) was set to output the first tone of each melody at 75 dB SPL in the soundfield. Based on pilot results, infants were tested in their ability to notice a 2.8% change in the fifth note of each melody, and adults were tested on 0.4% or 1.6% changes (Table 2).

Apparatus

Experimental sessions were conducted in a double-walled, sound-attenuated booth containing a video camera, a high-fidelity loudspeaker (Pioneer HPM 100), and a computer-monitored response panel. The experimenter used this panel to initiate trials and to record subject responses. Visual reinforcers consisted of four animated stuffed toys in four separate compartments concealed in a smoked plexiglass box. The computer randomly activated one of the four toys and illuminated one compartment as visual reinforcement.

Procedure

In the operant head-turn paradigm (Eilers & Gavin, 1981; Eilers et al.,

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Table 1. *Frequency values of melody notes (ratios, intervals, and onset times relate to the first note)*

Note	1	2	3	4	5	6	7
Delay of note onset from 0 ms	0	500	1000	1500	2000	3000	4000
Major Frequency, cps	293.7	329.6	370.0	392.0	440.0	370.0	293.7
Frequency ratio	1.0000	1.1225	1.2599	1.3349	1.4983	1.2599	1.0000
Note name	D4	E4	F#4	G4	A4	F#4	D4
Minor Frequency, cps	293.7	329.6	349.2	392.0	440.0	349.2	293.7
Frequency ratio	1.0000	1.1225	1.1892	1.3349	1.4983	1.1892	1.0000
Note name	D4	E4	F4	G4	A4	F4	D4
Pelog Frequency, cps	293.7	311.7	341.2	390.7	436.2	341.2	293.7
Frequency ratio	1.0000	1.0613	1.1617	1.3303	1.4852	1.1617	1.0000

1977), subjects were tested in discrimination of a well-tuned version of a melody from one in which the fifth note was mistuned by raising its frequency. The well-tuned melody (Sb), based on either the major, minor, or pelog scale depending on the testing condition, was played repeatedly through a loudspeaker. Sb was presented continuously except when the fifth note was changed (Sd). Each session began with a shaping phase in which Sd was accompanied by 12, 8, and 4 dB intensity changes from Sb. Two trials at each level of intensity change were conducted. Shaping was followed by 30 equal-intensity test trials, 15 experimental change trials and 15 control trials. The experimenter initiated trials by pressing a button on a concealed panel. If an adult subject raised a hand during a trial interval, the experimenter pressed a response button to record the hand-raise. Only hand-raises during experimental trials were correct, as indicated to the subjects by activation of an electronic toy in a smoked plexiglass compartment above the speaker from which the stimuli were played. Infants responded by turning their heads toward the loudspeaker in anticipation of the visual reinforcer. Responses during both change and control trials were recorded for analysis.

Infants were tested in perception of a 2.8% increase in the frequency of the fifth note, and adults were tested on 1.6% and 0.4% frequency increases (Table 2). Before testing, 10 infants were trained to notice a 5.0% increase in the frequency of the fifth note of the pelog melody, and 10 infants were trained on the major melody. Training criterion was reached when a subject correctly responded to 9 out of 10 consecutive trials (randomly experimental and control trials). The training procedure was not necessary for the adults. During testing sessions, the experimenter was fitted with earplugs and with headphones through which loud masking music was played. Presentation of the major, minor, and pelog melodies was counterbalanced across subjects within each age and musical experience group.

RESULTS

The infants' performance did not differ as a function of the musical scale on which the melody was based (overall means: major = 67.1%; minor = 65.8%, pelog = 67.3%, see Figure 1). A 3 (Scale Type: major, minor, and pelog) × 2 (Training Condition: major, pelog) × 3 (Block) Analysis of Variance (ANOVA) was conducted on the infants' data. The Block factor was included in order to assess potential effects of either fatigue or learning within each test session. Each session included three blocks of 10 trials each (first 10 trials, second 10 trials, and third 10 trials). The main effect of Scale Type was not significant, confirming that the subjects' performance was not systematically different across the native and non-native scales. Only the main effect of Training Condition was significant ($F(1,54) = 8.49$, $p < .005$). suggesting that the scale used in training may have affected the infants' absolute levels of performance on the three scales, but the lack of a significant Scale Type × Training Condition interaction indicates that the infants' pattern of performance across the scales was not affected. Infant performance was significantly better than chance (chance = 50% correct) by *t*-tests (two-tailed) on all scales ($df = 9$, $p < .01$).

Since the infants' performance was not significantly different across the Western and Javanese scales, a power analysis (Kraemer & Thiemann, 1987, p. 47) was conducted to insure that a sufficient sample size was used. The averaged standard deviation (*SD*) of all adult and infants groups at each level of mis-

Table 2. *Frequency values of top (fifth) melody note for each amount of frequency change (ratios and intervals relate to well-tuned note)*

		Infants	Adults	
	Well-Tuned	2.8% Change	0.4% Change	1.6% Change
Frequency, cps	440.0 (MAJ, MIN)	452.3	441.8	447.0
	436.2 (PEL)	448.4	437.9	443.2
Frequency ratio		1.028	1.004	1.016

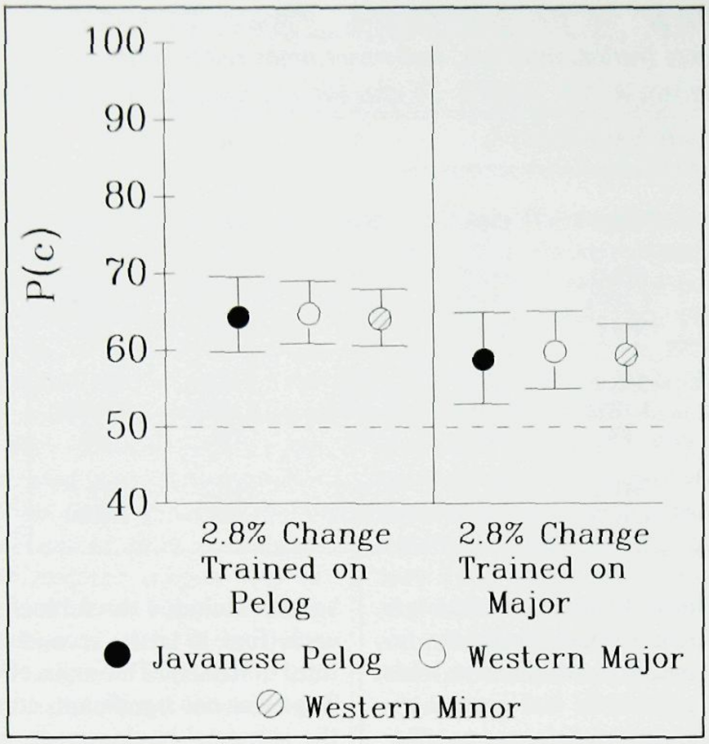

Fig. 1. Infants' mean percentage correct and 95% confidence limits. Dashed lines indicate change. In the left-hand column, 10 infants were trained on a 5.0% change in the fifth note of the pelog melody and subsequently tested on a 2.8% change in the fifth note of the major, minor, and pelog melodies. In the right column, 10 infants were trained on a 5.0% change in the fifth note of the major melody and subsequently tested on a 2.8% change in fifth note of the major, minor, and pelog melodies.

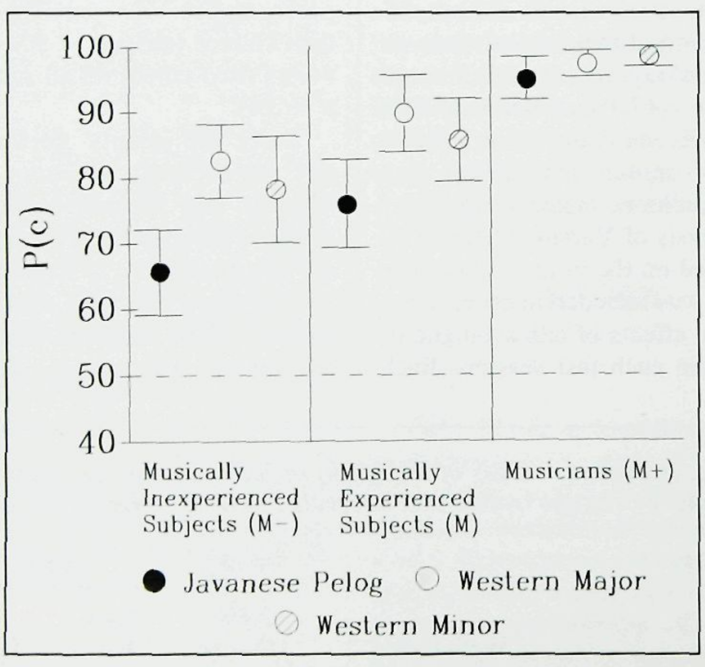

Fig. 2. Adult subjects' mean percentage correct and 95% confidence limits for each melody when the frequency of the fifth note of the major, minor, and pelog melodies was increased by 1.6%. The dashed line indicates chance.

tuning was used as the best estimate of the population standard deviation (Adults SD = 14.23%, Infants SD = 13.22%, Overall SD = 13.96%). Based upon the significant differences that were found in the adults' data (see below), 10 percentage points was selected as the minimum difference for detection between any two means. The power of this study to detect a 10 percentage point difference in performance between the major and pelog scales was 0.9, between the major and minor scales was 0.8, and between the minor and pelog scales was 0.8.

In contrast to the infants, the adults' performance was better on the native than non-native scales (overall means: major = 74%, minor = 72%, pelog = 66%, see Figures 2 and 3), suggesting that their perception was affected by musical acculturation. A 3 (Scale Type: major, minor, pelog) × 3 (Musical Experience: M−, M, M+) × 2 (Frequency Change: 0.4%, 1.6%) × 3 (Block) ANOVA was conducted. The significant main effect of Scale Type ($F(2,162) = 16.67$, $p < .0001$) confirmed that the adults were better perceivers of native than non-native scales. Additionally, the main effects of Musical Experience ($F(2,81) = 41.25$, $p < .0001$) and Frequency Change ($F(1,81) = 401.1$, $p < .0001$) were significant. As expected, subjects with musical experience performed better than musically inexperienced subjects (overall means: M− = 61%, M = 70%, M+ = 80%), and the 1.6% frequency change (M = 85%) was easier to detect than the 0.4% frequency change (M = 55%). The significant Scale Type × Musical Experience × Frequency Change interaction ($F(4,162) = 2.89$, $p < .025$) suggested, however, that patterns of performance across the native and non-native scales differed for the M−, M, and M+ subjects. This interaction was examined by conducting separate 3 (Scale Type) × 2 (Frequency Change) × 3 (Block) ANOVAs for each of the adult groups.

The musically inexperienced (M−) subjects' performance was better on the native than non-native scales (overall means: major = 65%, minor = 63%, pelog = 56%). This pattern was confirmed in the 3 × 2 × 3 ANOVA, in which the main effect of Scale Type ($F(2,54) = 6.48$, $p < .005$) was signifi-

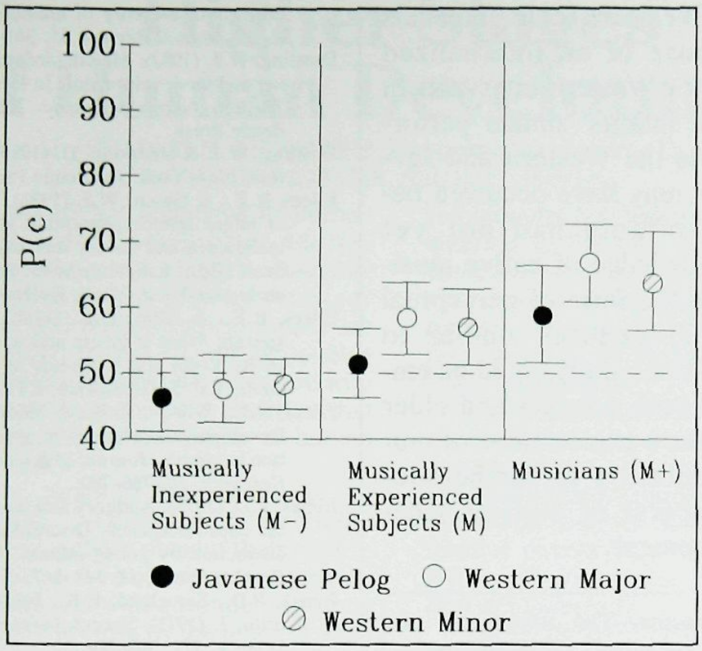

Fig. 3. Adult subjects' mean percentage correct and 95% confidence limits for each melody when the frequency of the fifth note of the major, minor, and pelog melodies was increased by 0.4%. The dashed line indicates chance.

cant. Additionally, the Frequency Change × Scale type interaction was significant ($F(2,54) = 6.97$, $p < .002$). This interaction was investigated by conducting separate 3 (Scale Type) × 3 (Block) ANOVAs for each level of the Frequency Change factor. The main effect of Scale Type was significant for the 1.6% test ($F(2,54) = 13.4$, $p < .0001$), and the M− subjects' performance was significantly better on the major and minor melodies than on the pelog melody (Duncan's Range Statistic, $p < .01$). Major and minor performance was not significantly different. Performance was significantly better than chance for all scales in the 1.6% test ($p < .05$), but performance was not significantly different from chance in the 0.4% test for any scale. Additionally, the M− subjects performed better on the 1.6% test (M = 75%) than on the 0.4% test (M = 48%), as indicated by the significant main effect of Frequency Change ($F(1,27) = 88.31$, $p < .0001$).

The musically experienced (M) subjects' performance was also better on the native than non-native scales (overall means: major = 74%, minor = 71%, pelog = 63%). This pattern was confirmed in the 3 × 2 × 3 ANOVA, in which the main effect of Scale Type ($F(2,54) = 8.89$, $p < .0001$) was significant, and the M subjects' performance was significantly better on the major and minor melodies than on the pelog melody (Duncan's Range Statistic, $p < .05$). Major and minor performance was not significantly different. The M subjects' performance was significantly better than chance on all scales in the 1.6% test ($p < .01$), but it was not significantly different from chance on any scale in the 0.4% test. Similarly to the M− subjects, the M subjects performed better on the 1.6% frequency change (M = 84%) than on the 0.4% frequency change (M = 56%), as confirmed by the significant main effect of Frequency Change ($F(1,27) = 120.47$, $p < .0001$).

In contrast to the M− and M groups, the musician (M+) subjects' performance differed only slightly as a function of scale type (overall means: major = 82%, minor = 81%, pelog = 77%). In the 3 × 2 × 3 ANOVA, only the main effect of Frequency Change was significant ($F(1,27) = 242.38$, $p < .0001$), confirming that their performance was better for the 1.6% (M = 85%) than for the 0.4% (M = 55%) frequency change. Although the M+ group's performance across scale types was not significantly different in the ANOVA, their performance was significantly above chance in the 0.4% test on the major scale only (t-tests, two-tailed, $df = 9$, $p < .01$), suggesting that they were somewhat better perceivers of this scale than of the minor and pelog scales.

DISCUSSION

In summary, this study indicated that 6-month-olds' abilities to perceive mistunings were not influenced by the familiarity of the underlying scale, suggesting that infants may be born with an equipotentiality for the perception of scales from a variety of cultures. A similar hypothesis, advanced in the study of infant speech perception, proposes that infants are born with an equipotentiality for perception of the speech sounds of any language (Eimas, 1975; Eimas, Siqueland, Jusczyk, & Vigorito, 1973). The infants' performance across the native and non-native scales in the present study, while supporting this "innateness" hypothesis in terms of music, challenges an anithetical hypothesis which has been proposed by music theorists and general auditory scientists for many years. This second hypothesis suggests that Western scales should be inherently easier to perceive because their intervals approximate small-integer frequency ratios, which are proposed to be more readily processed by the human auditory system than the more complex ratios of some other cultures, such as that of Java (Burns & Ward, 1982). The infants' similar performance across Western and Javanese scales suggests that Western scale processing is not inherently easier than non-Western processing.

Since only one note was mistuned in the melodies, it is reasonable to consider the possibility that subjects did not attend to the surrounding tones in order to discriminate between the well-tuned and mistuned melodies (Cohen, Thorpe, & Trehub, 1987). A previous study (Lynch, Eilers, Oller, Urbano, & Wilson, 1989) of adults' perception of the major, minor, and pelog melodies, however, indicated that musically inexperienced and musician subjects' relative performance on these Western and Javanese melodies was maintained whether the mistuned tone was always the highest note in the melody or whether the serial location of the mistuning was made unpredictable by changing its position across trials. Thus, when the testing procedure required that every melodic interval be attended to in order to detect an unpredictably located mistuning, adults' relative performance across the Western Javanese melodies was not different from the present results. Although data are not yet available, it is reasonable to suspect that infants' patterns of performance across musical scales would, similarly to adults', not be affected by variable locations of mistunings. Further research using a changing location of mistuning with infant subjects could further clarify this issue.

The adults' better perception of native than non-native scales agrees broadly with previous studies (Castellano, Bharucha, & Krumhansl, 1984; Kessler, Hansen, & Shepard, 1984). The developmental nature of the present study, however, allows for the interpretation that substantial musical acculturation occurs between infancy and adulthood. Borrowing from a classic theory of cognitive psychology (Bartlett, 1932), several researchers (Dowling, 1978; Krumhansl & Shepard, 1979; Shepard & Jordan, 1984) have suggested that musical acculturation results in the development of scale-specific schemata. Western mistunings may have been easier for the adults to notice than Javanese mistunings because the Western scale intervals matched those of an internalized framework for Western intervals. In contrast, the infants' similar performance across the Western and Javanese scales may have occurred because the infants had not yet acquired knowledge of native musical scales in the form of perceptual schemata. Procedures similar to those used in this study could be employed with both younger and older infants in future explorations of musical acculturation to further describe the course of musical schemata development.

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REFERENCES

Aslin, R.N., & Pisoni, D.B. (1980). Some developmental processes in speech perception. In G.H. Yeni-Komshian, J.F. Kavanagh, & C.A. Ferguson (Eds.), *Child phonology, Volume 2: Perception*. Cambridge, England: Cambridge University Press.

Bartlett, F.C. (1932). *Remembering*. Cambridge, England: Cambridge University Press.

Burns, E.M. & Ward, W.D. (1982). Intervals, scales, and tuning. In D. Deutsch (Ed.), *The psychology of music* (pp. 241–269). New York: Academic Press.

Castellano, M.A., Bharucha, J.J., & Krumhansl, C.L. (1984). Tonal hierarchies in the music of North India. *Journal of Experimental Psychology: General, 113*, 394–412.

Cohen, A.J., Thorpe, L.A., & Trehub, S.E. (1987). Infants' perception of musical relations in short transposed tone sequences. *Canadian Journal of Psychology, 41*, 33–47.

Dowling, W.J. (1978). Scale and contour: Two components of a theory of memory for melodies. *Psychological Review, 85*, 341–354.

Dowling, W.J. (1982). Melodic information processing and its development. In D. Deutsch (Ed.), *The psychology of music*. New York: Academic Press.

Dowling, W.J. & Harwood, D. (1986). *Music cognition*. New York: Academic Press.

Eilers, R.E., & Gavin, W.J. (1981). The evaluation of infant speech perception skills: Statistical techniques and theory development. In R.E. Stark (Ed.), *Language behavior in infancy and early childhood*. North Holland: Elsevier.

Eilers, R.E., & Oller, D.K. (1988). Precursors to speech: What is innate and what is acquired? In R. Vasta (Ed.), *Annals of child development, Vol. 5*. Greenwich, CT: JAI Press.

Eilers, R.E., Wilson, W.R., & Moore, J.M. (1977). Developmental changes in speech discrimination in infants. *Journal of Speech and Hearing Research, 20*, 766–780.

Eimas, P.D. (1975). Auditory and phonetic coding of the cues for speech: Discrimination of the r-l distinction by young infants. *Perception and Psychophysics, 18*, 341–347.

Eimas, P.D., Siqueland, E.R., Juszyk, P., & Vigorito, J. (1973). Speech perception in infants. *Science, 171*, 303–306.

Hulse, S.H., & Page, S.C. (1988). Toward a comparative psychology of music perception. *Music Perception, 5*, 427–452.

Jakobson, R. (1968). *Child language, aphasia, and phonological universals*. The Hague: Mouton. (originally published 1941).

Kessler, E.J., Hansen, C., & Shepard, R.N. (1984). Tonal schemata in the perception of music in Bali and in the West. *Music Perception, 2*, 131–165.

Kraemer, H.C., & Thiemann, S. (1987). *How many subjects? Statistical power analysis in research*. Newbury Park, CA: Sage.

Krumhansl, C.L., & Shepard, R.N. (1979). Quantification of the hierarchy of tonal functions within a diatonic context. *Journal of Experimental Psychology: Human Perception and Performance, 5*, 579–594.

Kunst, J. (1973). *Music in Java: Its history, its theory, and its technique*. The Hague: Martinus Nijhoff.

Lynch, M.P., Eilers, R.E. Oller, D.K., Urbano, R.C., & Wilson, P. (1989). *The role of musical experience in the perception of native and non-native musical scales*. Manuscript submitted for publication.

Nettl, B. (1956). *Music in primitive culture*. Cambridge, MA: Harvard University Press.

Pick, A.D. (1979). Listening to melodies. In A.D. Pick (Ed.), *Perception and its development*. Hillsdale, NJ: Erlbaum.

Shepard, R.N. & Jordan, D.S. (1984). Auditory illusions demonstrating that tones are assimilated to an internalized musical scale. *Science, 226*, 1333–1334.

Trehub, S.E. (1987). Infants' perception of musical patterns. *Perception and Psychophysics, 41*, 635–641.

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