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Revisiting the Innate Preference for Consonance

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The origin of the Western preference for consonance remains unresolved, with some suggesting that the preference is innate. In Experiments 1 and 2 of the present study, 6-month-old infants heard six different consonant/dissonant pairs of stimuli, including those tested in previous research. In contrast to the findings of others, infants in the present study failed to listen longer to consonant stimuli. After 3 minutes of exposure to consonant or dissonant stimuli in Experiment 3, 6-month-old infants listened longer to the familiar stimulus, whether consonant or dissonant. Our findings are inconsistent with innate preferences for consonant stimuli. Instead, the effect of short-term exposure is consistent with the view that familiarity underlies the origin of the Western preference for consonant intervals.

Keywords: infants, music, consonance, dissonance, preference

Music is present in all human societies, but its form varies widely across cultures and historical periods. The perception of various aspects of music such as pitch (Lynch, Eilers, Oller, & Urbano, 1990; McLachlan, Marco, Light, & Wilson, 2013) and meter (Hannon & Trehub, 2005a, 2005b; Kalender, Trehub, & Schellenberg, 2013; Phillips-Silver & Trainor, 2005, 2007) is shaped by experience. Aesthetic judgments are also shaped by experience, with interpretations of various aspects of music arising from cultural traditions and personal listening histories (Dowling & Harwood, 1986; Vassilakis, 2005). For example, beating or roughness from simultaneously sounded tones with overtones that are close but not identical in frequency (resulting in rapid amplitude fluctuations) is typically considered unpleasant by Western music listeners and designated as dissonant. In a number of other cultures, however, beating is evaluated neutrally or favorably. For example, pairs of instruments in Balinese gamelan orchestras are deliberately tuned to produce beats when played together, resulting in music considered “lively and full” (Schmidt-Jones, 2011). Beats are acceptable, even desirable, in Middle Eastern, North Indian, and Bosnian musical cultures (Vassilakis, 2005). Some North Indian *rags* contain prolonged notes that produce beats (minor seconds) in relation to the drone (Maher, 1976). In traditional *ganga* singing of rural Croatia, two vocalists produce the same melody one semitone apart, with resulting beating (Vassilakis, 2005). Harmonizing on dissonant intervals has been noted in a number of widely separated cultures (Jordania, 2006). Such cross-cultural differences in attitudes toward beating, although widely acknowledged in ethnomusicology, are largely ignored in psychoacoustics and music cognition (but see Burns, 1999; Butler & Daston, 1968; Guernsey, 1928).

Nevertheless, there are persistent claims of innate human preferences for consonance. Such claims arise from infants’ longer listening times to tone combinations that generate little or no roughness than to those that generate considerable roughness (Crowder, Reznick, & Rozenkrantz, 1991; Masataka, 2006; Trainor & Heinmiller, 1998; Trainor, Tsang, & Cheung, 2002; Zentner & Kagan, 1998). How can we reconcile claims of innately favorable dispositions for tone combinations considered consonant in Western music with the documented differences in preference across cultures?

The dominant theoretical account of the consonance of tone combinations in Western music is based on the smoothness of sound that occurs in the absence of beating, in contrast to the rough-sounding quality of dissonance (Helmholtz, 1887/1954; Kameoka & Kuriyagawa, 1969; Plomp & Levelt, 1965). Originally, combinations of tones whose fundamental frequencies form simple (i.e., small-integer) ratios were considered consonant, and those whose fundamental frequencies form complex (i.e., large-integer) ratios were considered dissonant (see Tenney, 1988 for historical perspectives on consonance). Critical bands, or the frequency bandwidth of cochlear filters (Kameoka & Kuriyagawa, 1969; Plomp & Levelt, 1965), provided a physiological basis for what came to be known as sensory consonance and dissonance. Intervals with simple ratios (e.g., octave or 2:1 ratio, perfect fifth or 3:2 ratio) have many harmonics in common and few that interact (i.e., interfere with one another) within a critical band so that there is little beating. By contrast, intervals with complex ratios (e.g., minor second or 16:15 ratio) have many interacting harmonics within a critical band, resulting in beating or roughness. In fact, Western listeners’ ratings of the pleasantness of isolated intervals are coarsely aligned with the degree of consonance based on frequency ratios (Guernsey, 1928; Valentine, 1962; Van De Geer, Levelt, & Plomp, 1962).

Aside from cross-cultural practices, which call into question universal associations between beating and unpleasantness, Western music theory has witnessed changing conceptions of consonance and dissonance over the course of history (Tenney, 1988). Pythagoras (6th century BC) defined consonant tone combinations as successive tones having fundamental frequencies that formed

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simple ratios. The later introduction of polyphony (simultaneous tones) led to increased use of some intervals and to their altered designations from dissonant to consonant. As the emphasis on harmony, or the vertical structure of music, became more prominent, the quality assigned to an interval (two simultaneous tones) or chord (three or more simultaneous tones) was increasingly based on the role of the chord or interval within a particular harmonic context instead of fundamental frequency ratios. Consequently, the very same chord might be consonant in one context and dissonant in another without regard to the presence or absence of beating. There is widespread acknowledgment that culture-specific knowledge of music affects this conception of consonance and dissonance, which has become known as musical consonance (Cazden, 1980). According to Terhardt (1978, 1984), musical consonance, although affected by learning, is rooted in sensory factors.

Although Western adults typically rate isolated consonant intervals as more pleasant than dissonant intervals, they do not assign the highest ratings to intervals with the simplest ratios, notably the octave (12 semitones, 2:1 ratio) and perfect fifth (seven semitones, 3:2 ratio) (Guernsey, 1928; Guthrie & Morrill, 1928; Valentine, 1962; Van De Geer et al., 1962). Intervals rated highest in pleasantness are major and minor sixths (nine semitones, 5:3 ratio; eight semitones, 8:5 ratio) and major and minor thirds (four semitones, 5:4 ratio; three semitones, 6:5 ratio), and the interval rated most unpleasant is the minor second (one semitone, 16:15 ratio) rather than the tritone (six semitones, 45:32 ratio) (Butler & Daston, 1968; Guernsey, 1928; Valentine, 1962; Van De Geer et al., 1962). Moreover, the pleasantness ratings of musicians are more highly correlated with frequency ratio simplicity than are those of musically untrained listeners (Bugg, 1939; Guernsey, 1928; Malmberg, 1918; Roberts, 1984).

If beating underlies the documented pattern of preferences, then it is unclear why the pleasantness ratings of musicians and non-musicians diverge although their ratings of beating do not (Guernsey, 1928). Interestingly, listeners with impaired pitch perception rate consonant intervals as no more pleasant than dissonant intervals even though their perception of beating is comparable with that of listeners with intact pitch perception (Cousineau, McDermott, & Peretz, 2012; Tramo, Cariani, Delgutte, & Braida, 2001). The implication is that evaluations of pleasantness are unrelated to beating.

A longstanding but less popular alternative explanation of the apparent pleasantness and unpleasantness of consonant and dissonant intervals links the harmonicity or harmonic relations among component frequencies of consonant intervals (i.e., component frequencies being integral multiples of the fundamental frequency) to pleasantness and the inharmonic relations among the components of dissonant intervals to unpleasantness (e.g., Terhardt, 1974; Tramo et al., 2001). Beating and inharmonic relations are normally correlated, which makes it difficult to assess their independent contributions to pleasantness. McDermott, Lehr, and Oxenham (2010) found, however, that individual differences in preferences for harmonicity predicted the preferences for consonant intervals and chords, but preferences for stimuli with or without beats did not predict preferences for consonance. Moreover, preferences for harmonicity and consonance ratings were correlated with years of music training, indicating that experience influences the strength of such preferences.

Developmentally, preferences for consonant over dissonant intervals are not apparent in Western 6-year-olds; they begin to emerge at about 9 years of age and become adult-like at 12, with musical training accelerating the timetable (Valentine, 1962). Familiarity or learning accounts of consonance and dissonance recently received a definitive boost from the demonstration that pitch-matching training on randomly selected intervals of simultaneous pure tones leads to lower dissonance ratings (defined for listeners as roughness, harshness, unpleasantness, or difficulty listening to the stimuli) for trained but not for untrained tone combinations (McLachlan et al., 2013).

How can we fit the infant preference data with contradictory information and findings from other sources? The infant studies of consonance generally use a head-turn or visual preference procedure in which the presentation of auditory stimuli is contingent on visual fixation (Masataka, 2006; Trainor & Heinmiller, 1998; Trainor et al., 2002). Longer looking time during the presentation of one stimulus (e.g., consonant) is typically interpreted as a preference for that stimulus. Such measures of interest or attention are very different from the explicit aesthetic judgments obtained in studies of older children and adults. For adults, interest in a stimulus is related to its novelty, complexity, and comprehensibility and may be dissociated from aesthetic preference (Silvia, 2005). Initial interest in a novel stimulus may be replaced by positive or negative evaluations after additional exposure. Infant listening times also change with exposure to a stimulus and with the delay between exposure and testing (Spence, 1996; Trainor, Wu, & Tsang, 2004). Accordingly, the suggestion that infants listen longer to one of two auditory patterns because they like or prefer it is highly speculative (Hunter & Ames, 1988). Infants' differential listening, although indicative of stimulus differentiation, is uninformative about aesthetic preferences, especially in the absence of additional behavioral or physiological measures that corroborate such interpretations (Trehub, 2012). Only Zentner and Kagan (1998), who used noncontingent presentation of consonant and dissonant stimuli, found negative affective reactions (e.g., distress vocalizations, turning away from the sound source) to the dissonant stimulus in a small minority of infants.

There are alternative explanations of the listening time differences in some of the infant studies. For example, Zentner and Kagan (1998) used larger consonant intervals (major thirds, four semitones) than dissonant intervals (minor seconds, two semitones) confounding interval size and consonance/dissonance. The stimuli in Crowder, Reznick, and Rozenkrantz (1991) differed in pitch range and number of pitch classes. Interval size and pitch classes were matched across consonant and dissonant versions in the Trainor and Heinmiller (1998) and Masataka (2006) studies, both of which used the identical stimuli (synthesized piano version of a Mozart minuet). Although there are several published studies of infants' perception of consonance, a limited selection of stimulus material has been used.

In previous research, infants were tested with (a) the two most consonant intervals, perfect fifths and octaves, and the two most dissonant intervals, minor ninths (compound minor seconds) and tritones (Trainor & Heinmiller, 1998, Experiment 1; Trainor et al., 2002); (b) one consonant (C3, E4, G4, C5) and one dissonant (C3, C#4, F#4, B4) chord (Crowder et al., 1991); or (c) a melody in which each note was combined with another single note to yield mostly consonant or mostly dissonant intervals (Masataka, 2006;

Trainor & Heinmiller, 1998, Experiment 2; Zentner & Kagan, 1998). Musical pieces consisting almost entirely of such intervals or dyads are relatively rare. More commonly, accompaniment for melodies features chords (three or more simultaneous tones) with some but not all of the melody notes.

The present study was motivated by discrepancies between the results of studies with infants (e.g., Trainor & Heinmiller, 1998; Zentner & Kagan, 1998) and those with older children (Valentine, 1962) and by the limited range of stimuli used with infants. In the first experiment, we tested infants with unaccompanied melodies in which successive pitches (i.e., their fundamental frequencies) were related by simple or complex ratios (designated consonant and dissonant, respectively) and with the same melodies accompanied by consonant or dissonant chords. Replication of previous results with novel stimuli would confirm the generality of infants' greater interest in consonant than dissonant stimuli and motivate further developmental research to disentangle implicit biases from explicit preferences.

Experiment 1

We assessed 6-month-olds' listening times to unaccompanied and accompanied melodies with the head-turn preference procedure in which visual fixation is a proxy for listening. Listening was assessed in four conditions. In the first, one stimulus was a conventional 10-note melody (see Figure 1) used in previous research with infants, children, and adults (Trainor & Trehub, 1992, 1994). Most sequential intervals in the melody, which was designated consonant, had simple frequency ratios. Most sequential intervals in the contrasting melody, which was designated dissonant, had complex frequency ratios. Although infants exhibit enhanced processing (i.e., better short-term memory [STM]) for sequential intervals with simple frequency ratios over those with complex ratios (Schellenberg & Trehub, 1996), there has been no attempt to assess differential interest in such sequential intervals. For adults at least, processing advantages (e.g., better memory) do not necessarily predict aesthetic appeal (e.g., Weiss, Trehub, & Schellenberg, 2012). The second and third conditions featured the same two melodies accompanied by three-note chords for six of the 10 notes. The stimuli in the fourth condition consisted of actual piano performances of tonal and atonal compositions from the art music repertoire.

If ease of processing (Schellenberg & Trehub, 1996) promotes infants' interest, then we would expect infants to listen longer to melodies with simple-ratio intervals than to those with complex-ratio intervals. On the basis of previous research with consonant and dissonant intervals (Masataka, 2006; Trainor & Heinmiller, 1998; Trainor et al., 2002; Zentner & Kagan, 1998), we expected infants to listen longer to the consonant melodies accompanied by consonant chords than to the dissonant melodies accompanied by consonant or dissonant chords. Finally, the tonal and atonal compositions provided an opportunity to examine infants' responsiveness to musical performances that were highly contrastive in the incidence of sequential and simultaneous intervals with simple or complex frequency ratios.

Method

Participants. The participants were 64 healthy, full-term infants (26 males, 38 females) from middle-class families in an

Consonant melody with consonant harmony



Dissonant melody with consonant harmony



Dissonant melody with dissonant harmony



Figure 1. Musical stimuli from Experiment 1. The consonant melody accompanied by consonant chords is shown in the top panel, the dissonant melody with consonant chords in the middle panel, and the dissonant melody with dissonant chords in the bottom panel. Note that the consonant and dissonant melodies were identical across conditions, including the melody-alone condition that is not depicted.

ethnically and culturally diverse community surrounding the campus. The infants were 6 months of age ($M = 28.4$ weeks, $SD = 1.2$) and had no family history of hearing loss or personal history of ear infections. Each infant participated in only one of four conditions, with 16 infants in each condition. Data from an additional 14 infants were excluded from the sample because of experimenter error ($n = 3$), technical problems ($n = 3$), or parents' interaction with infants during the test session, contrary to instructions ($n = 8$). No infant became distressed during the test session.

Apparatus. Testing took place in a double-walled sound-attenuating booth (Industrial Acoustics Corporation 110766, 3 m \times 2.5 m) with dim lighting. There were three monitors: one directly in front of the infant at a distance of 1 m, one 45 degrees to the infant's right, and the other 45 degrees to the left. The presentation of stimuli and the recording and tabulation of responses were controlled by a custom-designed program (Realbasic) on a Windows XP workstation with SoundBlaster X-Fi Fatal1ty sound card. Sounds were delivered through an amplifier (Harmon/Kardon 3380) located outside the booth connected to two loudspeakers (Audiological GSI) located directly below each of the side monitors inside the booth. A Sony camcorder recorded images of the infant and transmitted them to a TV outside the booth.

Stimuli. Stimuli for the first three conditions were created in piano timbre with Finale software. The consonant and dissonant melodies, which consisted of 10 400-ms notes (overall duration of 4 s), were identical across the three conditions. For the consonant melody, of the nine intervals formed by its adjacent notes, six were consonant (major and minor thirds, perfect fourth, and perfect fifth) and three dissonant (major and minor seconds). The dissonant melody had the same starting note and pitch range, but seven of its nine intervals were dissonant (major and minor seconds and tritones), and the starting and ending notes differed. In each condition the stimuli were presented in three different keys (transpositions), C major, E major, and A major, with repetitions separated by 800 ms. The order of transpositions was randomized except for the constraint that successive repetitions were not presented at the same pitch level. Transpositions were ordered similarly across the three conditions.

In Condition 1, the simple melodies were presented. In Condition 2, the melodies had chord accompaniment that was consistent with the harmonic implications of the consonant melody and consisted of mainly consonant intervals (major and minor thirds, perfect fourth, perfect fifth, and major sixth). In relation to the notes of the consonant melody, the simultaneous (harmonic) intervals were primarily consonant (minor thirds, perfect fourths, perfect fifths, major sixths, and octaves, or their compound intervals). In relation to the notes of the dissonant melody, there were more simultaneous dissonant intervals (major and minor sevenths, and tritones; see Figure 1, top and middle panels). Because both melodies started on the same note and had the same accompanying chords, the consonant and dissonant versions in this condition both began with consonant harmony.

To create more dissonance in Condition 3, dissonant chords accompanied the dissonant melody (Figure 1, bottom panel). The result was many dissonant intervals (major and minor seconds, major and minor sevenths, and tritones) in the harmony as well as between the notes of the harmony and the melody. This dissonant stimulus began on a dissonant chord and had more dissonant intervals than the dissonant stimulus in Condition 2. The consonant version remained the same as in the Condition 2 (Figure 1, top panel). Sample consonant and dissonant stimuli from this condition are provided in supporting materials.

In Condition 4, the consonant stimulus consisted of three excerpts (11 s–14 s) from the second movement of Muzio Clementi's *Piano Sonata in F-sharp minor, Op.25 No. 5*, performed by Joseph Renouf. The dissonant stimulus consisted of three excerpts (8 s–16 s) from Luciano Berio's *Rounds* for piano solo (selected to exclude long silences) performed by Andrea Lucchesini. The consonant and dissonant musical material was roughly matched on tempo and the occurrence of single notes and chords. Adult listeners' ($n = 16$; eight trained musicians and eight nonmusicians) ratings of the pleasantness of consonant and dissonant versions of all stimuli on a 7-point scale (1 = *very unpleasant*, 7 = *very pleasant*) are shown in Table 1. A repeated-measures ANOVA with stimulus type (melody only, consonant melody with consonant chords, dissonant melody with consonant chords, dissonant melody with dissonant chords, Berio excerpts and Clementi excerpts) as within-subjects factors and music training as a between-subjects factor revealed a main effect of stimulus type, $F(6, 9) = 54.068$, $p < .001$, $\eta_p^2 = .97$, and no effect of musical training. The Clementi excerpts and the consonant melody received the highest ratings ($M = 5.87$, $SE =$

Table 1
Pleasantness Ratings (and Standard Error) Across Conditions in Experiment 1

| Stimuli | Rating (SE) |
|-----------------------------------------|-------------|
| Condition 1 | |
| Consonant melody | 5.56 (0.29) |
| Dissonant melody | 3.12 (0.31) |
| Condition 2 | |
| Consonant melody with harmony | 5.44 (0.27) |
| Dissonant melody with consonant harmony | 4.31 (0.40) |
| Condition 3 | |
| Consonant melody with harmony | 5.56 (0.29) |
| Dissonant melody with dissonant harmony | 3.50 (0.41) |
| Condition 4 | |
| Consonant (Clementi) | 5.87 (0.19) |
| Dissonant (Berio) | 2.52 (0.25) |

0.19 and $M = 5.56$, $SE = 0.29$, respectively), followed by the consonant melody with consonant harmony ($M = 5.43$, $SE = 0.27$), dissonant melody with consonant harmony ($M = 4.31$, $SE = 0.40$), dissonant melody with dissonant harmony ($M = 3.50$, $SE = 0.41$), dissonant melody ($M = 3.31$, $SE = 0.31$), and Berio excerpts ($M = 2.52$, $SE = 0.25$). Post hoc LSD tests revealed significant differences between unaccompanied consonant and the dissonant melodies, $p < .001$, consonant melody with consonant harmony and dissonant melody with dissonant harmony, $p < .001$, and between the Clementi and the Berio excerpts, $p < .001$. In short, adults' ratings approximated the presumed degree of consonance and dissonance of the stimuli.

Procedure. The infants sat on their parent's lap facing the central monitor. Parents wore headphones that delivered masking music to prevent them from hearing the auditory stimuli presented to infants. They were instructed not to interact with their infants except to return them to the original position, if necessary. An experimenter seated outside the booth observed the infant on an external TV (without sound) that displayed images from the camera in the booth. She depressed one key to indicate that the infant was looking at a side monitor in the booth and another to indicate looking away from that monitor. Custom software tabulated infant looking time for each trial and cumulative looking time for each stimulus type (consonant or dissonant). The experimenter was unaware of the stimuli being presented on any trial. Each trial began with the central screen flashing red. When the experimenter indicated that the infant was fixated on the central monitor, that screen stopped flashing and a side screen began flashing. When the experimenter indicated that the infant was fixated on the side monitor, a high-resolution image of a checkerboard with central red dot appeared at that locus, and an auditory stimulus (e.g., consonant version) was presented. The stimulus repeated in transposition until the infant looked away from the monitor for 2 s, at which time the music stopped and the visual display disappeared, leaving a black screen. The center screen flashed to regain infants' attention at midline. Once central fixation was achieved, flashing began on the screen on the opposite side. Fixation on that screen initiated the same checkerboard pattern in conjunction with the contrasting auditory stimulus (e.g., dissonant version). Again, the visual and auditory stimuli continued until the infant looked away for 2 s. Infants in Condition 1 were presented with the consonant

and dissonant melodies. Infants in Condition 2 were presented with the consonant melody with consonant harmony and the dissonant melody with the consonant harmony. Infants in Condition 3 were presented with the consonant melody with consonant harmony and the dissonant melody with dissonant harmony. Infants in Condition 4 were presented with the Berio and Clementi excerpts. Consonant and dissonant stimuli were presented on alternating trials, and there were 12 trials, 6 of each type. In Condition 4 the consonant trials consisted of the three Clementi excerpts and the dissonant trials consisted of three Berio excerpts. One excerpt was played on each trial and presented twice in fixed order in the course of the test session for a total of six of each type. The location of consonant and dissonant stimuli was consistent for individual infants, but the location of first presentation (left or right) and the first stimulus (consonant or dissonant) were counterbalanced across infants.

Results and Discussion

Results for each condition were analyzed separately to facilitate comparisons with similar test conditions in previous studies of infant preferences for consonance. ANOVAs with stimulus type (consonant, dissonant) as a within-subjects factor and side of initial presentation and first stimulus as between-subjects factors revealed no significant main effects or interactions. Infants looked no longer to hear the consonant stimulus than the dissonant stimulus in any of the four conditions (see Figure 2), and there was no effect of first side of presentation (left or right) or stimulus heard first (consonant or dissonant). These results fail to replicate previously reported findings of longer listening for consonant than for dissonant stimuli (Crowder et al., 1991; Masataka, 2006; Trainor & Heinmiller, 1998; Trainor et al., 2002; Zentner & Kagan, 1998).

Although looking times during the presentation of consonant and dissonant stimuli did not differ significantly in any of the conditions, actual looking times for dissonant stimuli were longer than those for consonant stimuli in all conditions. Collapsing across the four conditions, mean cumulative listening times to consonant and dissonant stimuli were 42.00 s ($SE = 3.00$) and 59.16 s ($SE = 6.44$), respectively. A repeated-measures ANOVA with stimulus type (consonant, dissonant) as a within-subjects

factor and condition (melody only, melody with consonant chords, melody with consonant/dissonant chords, real music) as a between-subjects factor revealed a main effect of consonance, $F(1, 60) = 4.727$, $p = .034$, partial $\eta_p^2 = .073$, but no effect of condition, $F(3, 60) = .127$, $p = .944$, and no interaction between stimulus type and condition. Of the 64 infants, 41 listened longer to the dissonant than to the consonant version, $p < .033$ (binomial test, two-tailed). The failure to replicate previous findings of longer looking times to consonant stimuli raises the question of whether that failure is attributable to stimulus differences. That question was the focus of Experiment 2.

Experiment 2a

The goal of the present experiment was to ascertain the replicability of the main findings on greater infant listening times for consonant musical patterns with the stimuli used in previous studies. Infants in the present experiment heard consonant and dissonant versions of the Minuet used by Trainor and Heinmiller (1998, Experiment 2) and Masataka (2006).

Method

Participants. The participants were 24 6-month-old infants (10 female, 14 male) from the same community as infants in Experiment 1. Infants were 6 months of age ($M = 28.3$ weeks, $SD = .94$) and had no family history of hearing loss or personal history of ear infections. Data from an additional six infants were excluded from the sample due to failure to complete the 20 trials because of fussiness ($n = 4$) or equipment failure ($n = 2$).

Apparatus, stimuli, and procedure. The apparatus was identical to that used in Experiment 1. The consonant and dissonant versions of the Mozart Minuet used in Trainor and Heinmiller (1998) were created using Finale software according to descriptions provided in the article. The procedure was identical to that of Experiment 1 except that infants were presented with 20 trials, 10 of each type, as in Trainor and Heinmiller (1998).

Results and Discussion

There were no differences in looking time to the consonant and dissonant stimuli, $t(23) = .398$, $p = .695$. A repeated measures ANOVA with stimulus type (consonant, dissonant) and test phase (first or second 10 trials) as within-subjects factors revealed no significant effect of stimulus type but a significant effect of test phase, $F(1, 23) = 9.487$, $p = .005$, $\eta_p^2 = .29$. This effect reflected infants' significant decline in looking to the consonant stimulus from the first ($M = 61.83$ s) to the second half ($M = 31.79$ s) of the test session, $t(23) = 3.432$, $p = .002$. The decline in looking to the dissonant stimulus from the first ($M = 50.28$) to the second half ($M = 38.25$) was not significant, $t(23) = 1.167$, $p = .25$. In fact, infants looked longer but not significantly so to the dissonant than to the consonant stimulus in the second half. In summary, we found no significant differences between infants' looking time to consonant and dissonant stimuli, which is to say that we failed to replicate the findings of Trainor and Heinmiller (1998) with the same stimuli and age group.

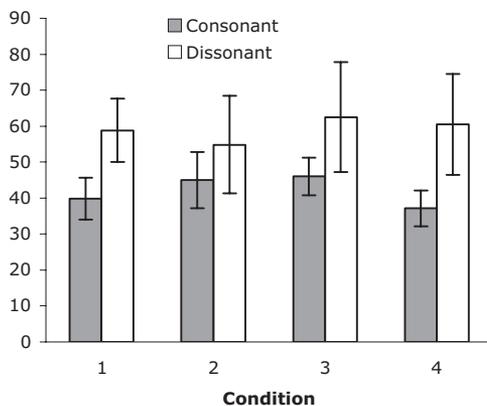


Figure 2. Mean cumulative looking time (seconds) to consonant and dissonant stimuli in each condition of Experiment 1. Error bars are standard errors.

Experiment 2b

Infants in this experiment were presented with the consonant and dissonant version of a folk song from Zentner and Kagan (1998) using the head-turn preference procedure.

Method

Participants. The participants were 16 6-month-old infants (seven female, nine male) from the same community as infants in Experiment 1. Infants' mean age was 28.2 weeks ($SD = 1.33$), and they had no family history of hearing loss or personal history of ear infections. Data from two additional infants were excluded from the sample due to equipment failure.

Apparatus, stimuli, and procedure. The apparatus was identical to that used in Experiment 1. The consonant and dissonant versions of Melody A, a Central European folk song used by Zentner and Kagan (1998), were created with Finale software according to descriptions provided in the article. The procedure was identical to that described in Experiment 1 with the exception that infants received 20 trials, 10 of each type. Zentner and Kagan (1998), by contrast, used a noncontingent procedure in which infants heard each of four stimuli (two folk songs in original or consonant versions and dissonant versions) for a fixed duration (35 s). They measured cumulative fixation for the two consonant stimuli and also for the two dissonant stimuli.

Results and Discussion

A repeated measures ANOVA revealed no effect of stimulus type on cumulative looking, $F(1, 15) = 1.82, p = .20$ (see Figure 3). Zentner and Kagan (1998) found significantly longer overall looking time for the consonant stimulus as well as significantly longer initial visual fixation for the consonant version. For our data set, a repeated measures ANOVA revealed significant differences in the duration of first fixation to each stimulus (i.e., a within-subjects comparison), $F(1, 15) = 4.80, p < .05$, with longer looking for consonant than for dissonant stimuli. This difference was no longer evident, however, when total looking times for the first two trials were considered (first consonant and first dissonant

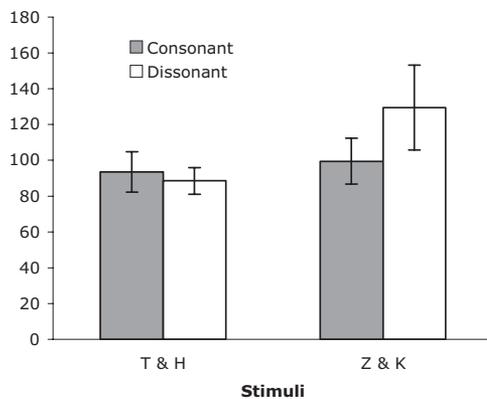


Figure 3. Mean cumulative looking times (seconds) to consonant and dissonant stimuli from Trainor and Heinmiller (1998), indicated as T & H, and Zentner and Kagan (1998), indicated as Z & H. Error bars are standard errors.

stimulus presentation, a within-subjects comparison), $F(1, 15) = .038, p = .85$. Again, we failed to replicate longer listening for consonant patterns with the specific stimuli used previously.

Preferences in infant research, as derived from greater looking time for one of two stimuli, have been attributed to the relative salience of the stimuli (Houston-Price & Nakai, 2004), which is influenced by infant age (Hunt, 1970), stimulus familiarity (Hunter & Ames, 1988), stimulus complexity (Richard, Normandeau, Brun, & Maillet, 2004), and the affective value or significance of the stimuli (Najm-Briscoe, Thomas, & Overton, 2000). In attempting to explain why our results differed from previous studies, we can probably rule out age differences. Our infants were the same age as those in Trainor and Heinmiller (1998) but 2 months older than those in Zentner and Kagan (1998). If the consonance preference is innate and evident from the newborn period (Masataka, 2006) through adulthood, as claimed (Valentine, 1962 being a notable exception), one would not expect relative listening times to be affected by this small age difference. It is difficult to speculate about differences in stimulus salience or significance across studies. It is interesting, however, that the decrease in listening times between the first and second half of the test session was greater for consonant than for dissonant stimuli in our replication of the Trainor and Heinmiller study (Experiment 2a). In other words, the relative salience or affective value of the stimuli seemed to change as a result of exposure to the stimuli within a single test session.

Of potential relevance is the fact that the present sample of infants differed from previous samples in its greater cultural diversity, which may have affected infants' exposure to sounds and to dissonant intervals in particular. Sounds and music heard in contemporary homes, with their numerous sound-making toys, gadgets, and appliances, are also likely to differ from those heard 25+ years ago when the original studies on infants' perception of consonance were conducted. Just as adults' musical exposure or training affects pleasantness ratings for consonant intervals (Bugg, 1939; Guernsey, 1928; Malmberg, 1918; McDermott et al., 2010; Roberts, 1984), the nature of infants' musical exposure may have contributed to the divergent listening patterns between the current study and earlier studies.

Although it is impossible to quantify infants' exposure to broad classes of stimuli such as consonant and dissonant patterns, it is possible to control their exposure to specific musical patterns in a laboratory setting. In Experiment 3 we use short-term exposure to examine the potential for shifting infants' inclination to listen to one stimulus or another. If exposure of this nature can affect listening inclinations, it should make one wary about drawing conclusions about innate preferences from relative listening times in infant experiments.

Experiment 3

For adults as well as children, the familiarity of music influences engagement with that music (Bradley, 1971; Fung, 1996; Krugman, 1943; North & Hargreaves, 1995; Pereira et al., 2011; Stevens & Latimer, 1991; Teo, Hargreaves, & Lee, 2008). Historically, familiarity has also affected judgments of tone combinations as pleasant or unpleasant (Tenney, 1988). According to Hunter and Ames' (1988) dynamic model of infant attention, infants exhibit a familiarity bias if their exposure to a stimulus has been insufficient for full encoding, with subsequent shifts to a novelty bias after

greater exposure. In previous research on infants' responsiveness to consonant music, the authors argued that consonant music had positive affective value independent of exposure (Masataka, 2006; Trainor & Heinmiller, 1998; Trainor et al., 2002; Zentner & Kagan, 1998). Others have argued, however, that the special status that seems to be apparent for some intervals is a consequence of exposure or enculturation (e.g., Burns, 1999; Dowling & Harwood, 1986).

Suggestions of a role for exposure, even brief exposure in the context of an experiment, can be found in the data of Trainor, Tsang, and Cheung (2002) from 2- and 4-month-old infants who listened to a series of consonant intervals followed by a series of dissonant intervals or the reverse. As can be seen in Figure 4, 2-month-olds listened longer to the dissonant series when it preceded the consonant series but to the consonant series when it preceded the dissonant (i.e., a significant interaction), and there was no main effect of consonance. Even for the most favorable order, consonant followed by dissonant trials, the consonance preference failed to reach conventional levels of significance, indicating that infants' preference for consonance is neither as strong nor as well established as presumed.

Our goal in the present experiment was to ascertain the consequences of limited preexposure to the stimuli from Condition 3 in Experiment 1 on infants' subsequent attention to those stimuli. Accordingly, we exposed one group of 6-month-old infants to the consonant melody with consonant chord accompaniment and another group to the dissonant melody with dissonant chord accompaniment. We then tested them on the consonant and dissonant patterns, one familiar, the other novel. Because of limited exposure to the stimulus, we predicted that infants would listen longer to the familiar than to the novel stimulus regardless of its consonance or dissonance. Such a finding would indicate that exposure to consonant and dissonant stimuli, even briefly, can have consequences for infants' subsequent listening behavior. Taken together with the nonreplication of previous findings, it would raise questions about the presumed innate preference for consonance.

Method

Participants. The participants were 16 healthy, full-term infants (11 male, five female) from middle-class families in an ethnically and culturally diverse community, as in Experiment 1. Infants were 6 months of age ($M = 27.4$ weeks, $SD = .92$) and had no family history of hearing loss or personal history of ear infections. Data from an additional seven infants were excluded from the sample because of infant fussiness ($n = 2$), technical problems ($n = 3$), or parents' interaction with infants during the test session ($n = 5$).

Apparatus and stimuli. The apparatus was identical to that used in Experiment 1. The stimuli were the consonant and dissonant versions used in the third condition of Experiment 1.

Procedure. The procedure began with a 3-min period of familiarization in which half of the infants heard the consonant melody accompanied by consonant chords (repeated in transposition) and the other half heard the dissonant melody with dissonant chords in transposition. These stimuli were identical to those used in Experiment 1, Condition 3. A silent video was displayed on the central screen during the familiarization phase, and the stimulus repeated with 800-ms interstimulus intervals without regard to infants' looking behavior. The familiarization phase was followed by a test phase that was identical to that described in Experiment 1.

Results and Discussion

Mean cumulative listening for the familiar and novel music was 69.02 s ($SE = 12.11$) and 40.66 s ($SE = 9.40$), respectively (see Figure 5). A repeated-measures ANOVA with familiarity (familiar, novel) as a within-subjects factor and consonance (consonance, dissonance) as a between-subjects factor revealed a main effect of familiarity, $F(1, 14) = 9.65$, $p = .008$, $\eta_p^2 = .41$, but no effect of consonance, $F(1, 14) = .004$, ns . Of the 16 infants, 15 listened longer during presentation of the familiar melody. In short, listening on test trials was influenced by the music heard in the immediately preceding familiarization phase. The endurance of this familiarization effect remains to be determined. A more im-

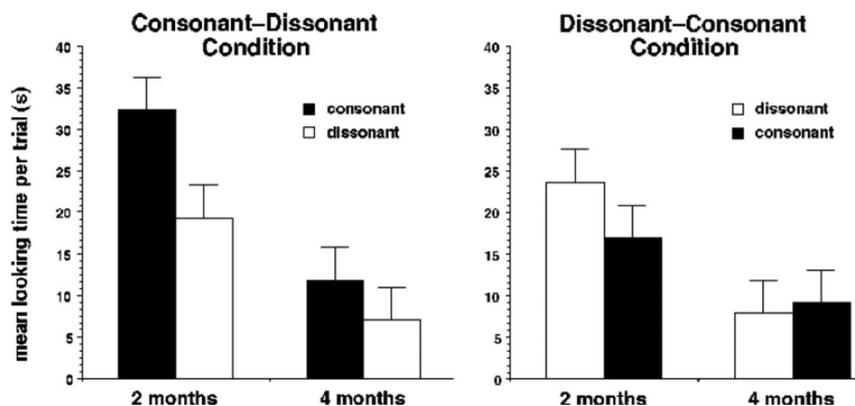


Figure 4. Mean looking times to consonant and dissonant stimuli for 2- and 4-month-old infants. Reprinted from *Preference for Sensory Consonance in 2- and 4-Month-Old Infants*, by L. J. Trainor, C. D. Tsang and V. H. W. Cheung, 2002, *Music Perception*, 20, page 191. Copyright [2002] by the Regents of the University of California. Reprinted with permission.

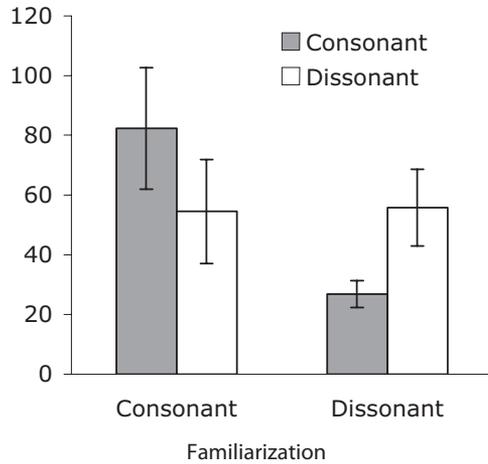


Figure 5. Mean cumulative looking (seconds) to consonant and dissonant stimuli as a function of familiarization with consonant and dissonant stimuli. Error bars are standard errors.

portant challenge for future research is to ascertain whether the present exposure effects are limited to the specific familiarization stimuli or whether they are applicable more broadly to other consonant or dissonant patterns.

General Discussion

We revisited the long-standing claims about innate preferences for consonance (Masataka, 2006; Trainor & Heinmiller, 1998; Trainor et al., 2002) because of their inconsistency with the emergence of consonance preferences at 9 years of age (Valentine, 1962), the impact of musical training or exposure on such preferences (McDermott et al., 2010; McLachlan et al., 2013), and differences in preferences and practices across cultures (e.g., Maher, 1976; Vassilakis, 2005) and historical periods (e.g., Tenney, 1988). Accordingly, we presented 6-month-old infants with consonant and dissonant stimuli in a series of experiments. In each of the four conditions of Experiment 1, infants listened no longer to the consonant than to the dissonant stimuli. The combined data from all conditions revealed that infants listened significantly longer to the dissonant than to the consonant stimuli. The difference between these findings and those of previous studies raised the possibility that stimulus differences were responsible for the divergent outcomes. In Experiment 2, we failed to find longer listening to consonant music with the identical stimuli used by Trainor and Heinmiller (1998, Experiment 2) and Zentner and Kagan (1998). The results from Experiments 1 and 2 are inconsistent with an innate preference or listening bias for consonant music (Masataka, 2006; Trainor & Heinmiller, 1998; Trainor et al., 2002; Zentner & Kagan, 1998). Indeed, careful reexamination of the previously published findings revealed that infants' preference for consonance is neither robust nor consistent across age (i.e., 2, 4, 6 months) or test procedures. In fact, the data from Trainor et al. (2002) seem to indicate that 4-month-olds' preference for consonance is weak or nonexistent (see Figure 4), in contrast to the consonance preference reported by Zentner and Kagan (1998) with same-age infants.

Infant listening times in Experiment 3 were influenced by the stimuli heard in the familiarization phase, regardless of whether they were consonant or dissonant. The same consonant and dissonant stimuli that failed to reveal differential listening in Experiment 1 resulted in significant differences when preceded by exposure to one of the stimuli. Longer listening to the familiar stimulus, emerging as it did after only 3 min of exposure, is difficult to reconcile with the innate and enduring preference for consonance that has been proposed. These findings are reminiscent of the contrasting "preferences" of 2-month-olds when a block of dissonant trials precedes or follows a block of consonant trials (Trainor et al., 2002; see Figure 4). Our results from short-term exposure are consistent with the enduring consequences of musical enculturation and training on evaluative responses to consonant and dissonant intervals in children (Valentine, 1962) and adults (Bugg, 1939; Guernsey, 1928; Malmberg, 1918; McDermott et al., 2010; McLachlan et al., 2013; Roberts, 1984). They are also consistent with the divergence of musical forms across cultures and with divergent evaluative responses to such forms (Brandt, Gebrian, & Slevc, 2012; Herzog, 1939; Jordania, 2006; Nettle, 2000; Vassilakis, 2005).

Undoubtedly, listeners from all cultures hear the beating or roughness generated by the nonoverlapping harmonics of simultaneous tones. Nevertheless, differences in music practice across cultures, as with North American and Indian listeners, result in divergent evaluative ratings (e.g., restful, restless) of specific intervals (Maher, 1976). In principle, initial affective biases are possible, but it is difficult to imagine *ganga* singers, gamelan players, and their audiences having to overcome innately driven preferences or aversions.

There are suggestions that infants are sensitive to beats or roughness (Schellenberg & Trainor, 1996). They exhibit processing advantages (i.e., better STM) for simultaneous pure-tone combinations with small-integer ratios over those with large-integer ratios when the distance between tones is large enough to preclude roughness, and they exhibit similar processing advantages for sequential combinations of pure tones that also lack roughness (Schellenberg & Trehub, 1996). As noted, processing advantages do not translate uniformly to preferences (Weiss et al., 2012).

According to one theory of aesthetics (e.g., Reber, Schwarz, & Winkielman, 2004), aesthetic pleasure or preference arises, in part, from the experience of processing fluency. Infants' perception of consonant stimuli provides no explicit evidence of aesthetic pleasure, but one can consider the possibility that processing fluency contributes to longer listening to one of two stimuli. Longer listening for consonant intervals was not corroborated in the present study (Experiments 1 and 2), contrary to the claims of innate preferences. Nevertheless, longer listening for specific consonant or dissonant stimuli following familiarization with one of the stimuli (Experiment 3) is potentially interpretable by increased processing fluency. Processing fluency may account for historical and cross-cultural differences in preferences. It is also compatible with the cognitive incongruence model of dissonance, which implicates adaptation to recognizable stimuli (McLachlan et al., 2013). In short, an innate preference for consonance is unsupported. Even the minority of scholars who embrace musical universals exclude consonant intervals from consideration (e.g., Brown & Jordania, 2013).

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