THE DEVELOPMENT OF EVALUATIVE RESPONSES TO MUSIC: *Infants Prefer To Listen To Consonance Over Dissonance*

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In Experiment 1, 6-month-old infants looked longer in order to listen to a set of consonant intervals than to a set of dissonant intervals. In Experiment 2, infants preferred to listen to the original version of a Mozart minuet than to a version altered to contain many dissonant intervals. Thus, although infants do not yet have the musical-system-specific knowledge of scale structure that is involved in adults' emotional reactions to music, infants are similar to adults in their evaluative reactions to consonance and dissonance.

infant **auditory perception** **music preference** **consonance** **dissonance**

INTRODUCTION

Considerable controversy surrounds the question of the origin, biological significance, and function of music (e.g., Dissanayake, 1992; Kogan, 1994; Lomax, 1968; Trehub & Trainor, in press; Winner, 1982). However, the universality of music points to an important role in emotional expression and communication that may have adaptive significance. Recent empirical research suggests that music may play an important role in state regulation and emotional communication between caregivers and infants (e.g., Trehub & Trainor, in press; Trainor, 1996; Trainor, Clark, Huntley, & Adams, 1997). From the newborn period, caregivers around the world sing to their infants (e.g., Trehub, Unyk, & Trainor, 1993a, b; Trehub & Trainor, in press), believing that music has the power to convey affect and alter

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state, such as when lullabies promote sleep in a restless infant. Caregivers are exquisitely sensitive to the perceptual capabilities of their infants, singing to them more slowly, at a higher pitch, with exaggerated rhythm, and in a more loving or emotionally engaging manner than when singing alone (Trainor, et al., 1997; Trehub & Trainor, in press). Caregivers also render their speech to infants in a sing song manner (e.g., Fernald, 1991; Papousek, 1992). If infants understand the emotional messages of the music and speech directed toward them, the evolutionary value of such activity is obvious: Emotional communication is crucial to survival.

Past research on the early development of musical perception has focused on infants' discrimination abilities (e.g., see Trehub, Schellenberg, & Hill, in press; Trehub & Trainor, 1993; Trehub, Trainor, & Unyk, 1993, for reviews), showing that infants can detect changes in pitch contour (i.e., whether the melody goes up or down) and pitch interval (pitch distance between two tones). Little research has examined whether infants have distinct *evaluative* responses to musical forms that convey different emotional messages to adults, but infants do show marked preferences for many other kinds of stimuli. For instance, breast-fed babies prefer to smell breast pads from their mother over those from another nursing mother (e.g., Cernoch & Porter, 1985) and a preference for sweet over acidic tastes is present in the newborn (Crook, 1987). In the visual domain, infants prefer to look at faces that are rated as attractive by adults over those rated as unattractive (e.g., Langlois, Ritter, Roggman, & Vaughn, 1991). Caregivers modify their speech to infants, raising it in pitch, slowing it in tempo, elongating vowels, and adding slow pitch contours with large frequency ranges (e.g., Fernald, 1991; Papousek, 1992). A number of studies have shown that infants prefer to listen to such infant-directed ("musical") over adult-directed speech, and show heightened emotional responses to the former (e.g., Cooper & Aslin, 1990; Fernald, 1993; Werker, & McLeod, 1989).

Infants also pay attention to infant-directed singing. When given a choice of listening to a recording of infant-directed singing versus a recording of the same mother singing the same song alone, they prefer to listen to the infant-directed version (Trainor, 1996). Emotional expression appears to be involved in this preference as the degree of infant preference is correlated with the proportion of adult raters who find the infant-directed version to be rendered in a more loving tone of voice than the non-infant-directed version. Infants also show differential behaviors when listening to a recording of a mother singing with the intention of putting her baby to sleep, versus a recording of the same mother singing the same song but with the intention of arousing and playing with her baby (Trainor & Rock, 1997).

While these studies indicate that infants have preferences and attend to emotional information, they have not linked infants' preferences to aspects of musical structure beyond performance or surface features such as voice quality, pitch height, and tempo. According to Meyer (1956), emotions in music arise as a function of the relation between musical events (sounds) and learned expectations generated through knowledge of the underlying structure of the musical system. Just as there are different languages, there are different musical systems, each employing different pitch interval relations or scales. This structure is learned through simple exposure: even musically untrained Western adults have implicit knowledge of Western musical pitch structure (e.g., Trainor & Trehub, 1992). However, 6- to 8-month-old infants do not (Lynch, Eilers, Oller, & Urbano, 1990; Trainor & Trehub, 1992). Therefore, any emotional reactions infants experience when listening to music cannot be based on musical-system-specific pitch structure, as Meyer (1956) proposed for adults.

Before concluding that musical pitch structure cannot generate emotional reactions in infants, however, the precursors of sensitivity to system-specific pitch structure need to be examined. One dimension of perceptual pitch space, that of consonance/dissonance, appears to play a role in virtually all musical systems (Schellenberg & Trehub, 1994b). Further, infants discriminate consonant from dissonant intervals (Schellenberg & Trainor, 1996; Schellenberg & Trehub, 1996; Trainor, 1997) and adults rate one extreme of this dimension as sounding "pleasant" or "beautiful" (e.g., van de Geer, Levelt & Plomp, 1962) and the other extreme as sounding "unpleasant" (e.g., ominous, solemn, dark; Wedin, 1972) and suitable for lamentation (Rigg, 1937). Thus, the consonance/dissonance di-mension appears to be a logical place to begin to examine the effect of musical pitch structure on infants' evaluative reactions.

The interval between two tones specifies the distance in pitch that separates them. In its most simple definition, consonant intervals are those that sound smooth or pleasant to adults, while dissonant intervals are those that sound rough or unpleasant (e.g., Plomp & Levelt, 1965; Schellenberg & Trehub, 1994b). While the perceived pleasantness of an interval can be affected by experience and the context in which the interval is heard (such effects are referred to as *musical consonance*, see Cazden, 1980), *sensory consonance* (also referred to as tonal, Plomp & Levelt, 1965, or psychoacoustic, Bregman, 1990, consonance) is perceived for intervals presented in isolation and is thought to result from relatively peripheral properties of the auditory system.

Sensory dissonance arises when two tones sounded simultaneously have non-identical harmonics (a complex tone with a fundamental frequency or pitch of 100 Hz can have energy at each harmonic: 100, 200, 300, Hz and so on) that are separated by less than a critical bandwidth (somewhat less than 3 semitones, where a semitone is 1/12 of an octave on a log frequency scale) (Kameoka & Kuriyagawa, 1969; Plomp & Levelt, 1965). The critical bandwidth corresponds to the width of the auditory filter characteristic of the basilar membrane in the inner ear (Greenwood, 1991). Hence, two simultaneous tones (or harmonics) separated by less than a critical band are not fully resolved by the ear and the beating (amplitude fluctuations) that arises from their interaction is perceived as roughness or dissonance.

The perceived consonance of an interval is a function of the simplicity of the ratio of the fundamental frequencies of its component tones rather than the pitch distance between them (Helmholtz, 1954). When the ratio of the fundamental frequencies of two tones can be expressed with small integers, the tones have many harmonics in common and relatively few that are less than a critical bandwidth apart. By contrast, when the fundamental frequencies are related by larger-integer ratios, the tones have fewer harmonics in common, and more that fall within a critical band. For example, the most consonant interval is the octave, with component fundamental frequencies standing in a 1:2 ratio. In this case, all harmonics of the upper tone are also harmonics of the lower tone. The second most simple ratio, 2:3, forms a perfect fifth, which is perceptually the second most consonant interval. Two dissonant intervals are the tritone (ratio 32:45) and the minor ninth (15:32), which have no low harmonics in common and many pairs that fall within a critical band. Pitch distance does not play a direct role in this classification. The two tones of the octave and perfect fifth are separated by 12 and 7 semitones, respectively, whereas those of the minor ninth and tritone are separated by 13 and 6 semitones, respectively.

Adults' sensitivity to the consonance/dissonance dimension emerges from three types of findings, spanning perceptual to aesthetic effects. First, consonant intervals are easier to process than dissonant intervals. From at least as young as 6 months of age, this is true of infants as well. It is easier for both age groups to detect changes in simultaneous (both tones sounded at the same time) consonant over dissonant intervals (Schellenberg & Trehub, 1996; Trainor, 1997). Further, it is easier for both age groups to detect changes in one note of a melody with prominent consonant intervals between successive tones than in a melody with prominent dissonant intervals (e.g., Schellenberg & Trehub, 1994a, 1996; Cohen, Thorpe, & Trehub, 1987; Trainor & Trehub, 1993a, b). Second, consonance is a dimension of the perceived similarity of intervals (Levelt, van de Geer, & Plomp, 1966). Again, this has been shown to be true of infants as well (Demany & Armand, 1984; Schellenberg & Trainor, 1996). Given a consonant interval, infants find it easier to detect a change to a dissonant interval than to another consonant interval, even when the change in pitch distance is greater in the latter case (Schellenberg & Trainor, 1996). Thus, two consonant intervals sound more similar than do a consonant and a dissonant interval.

The third type of finding is of most interest here: as described above, adults find consonant intervals more pleasant-sounding than dissonant intervals (e.g., see Schellenberg & Trehub, 1994b for a review). Crowder, Reznick, and Rosenkrantz (1991) reported that although infants showed no preference for a major over a minor chord (the former being somewhat more consonant than the latter), infants preferred to listen to a highly consonant (C_3 E_4 G_4 C_5 [130.8, 329.6, 392.0, 261.6 Hz]) over a highly dissonant (C_3 $C\#_4$ $F\#_4$ B_4 [130.8, 277.2, 349.2, 493.9 Hz]) chord. However, these chords differ in several ways (e.g., the range of the second chord is larger; the first chord contains 3 different pitch classes whereas the second chord contains 4). Zentner (1996) also reported that infants preferred to listen to consonant over dissonant intervals. However, interval size and pitch distance were completely confounded in this study (the consonant intervals were predominantly 3 or 4 semitones whereas the dissonant intervals were 1 semitone in size). It is possible that infants simply prefer larger over smaller intervals.

The present study examined preferences for consonant versus dissonant intervals that were matched for average interval size and transposed to a number of different pitch levels. The measure of infants' preference was relative looking time to consonant versus dissonant intervals. There is much evidence that looking time is a good measure of affective response as well as attentional preference. In the visual domain, infants, children, and adults all look longer at faces rated independently by adults as attractive than those rated as unattractive (e.g., see Langlois, Roggman, & Rieser-Danner, 1990). At the same time, infants show more positive affect to the "attractive" faces. In the auditory domain, infants both look longer at and show more positive affect for infant-directed over adult-directed speech (Werker & McLeod, 1989). Thus, we used the relative amount of time infants looked at visual displays in order to listen to the consonant versus dissonant intervals as the measure of infants' preference.

EXPERIMENT 1

Method

Participants

Twelve infants (6 male and 6 female), between 6 months 0 days and 6 months 28 days (M = 6 months 11 days) were tested. All were born within 2 weeks of term, weighed at least 2500 g at birth, and were healthy at the time of testing. A further 3 were excluded, 1 due to equipment failure, 1 for failing to turn his or her head, and 1 due to fussing. A t-test revealed that the performance of males and females did not differ.

Apparatus

The stimulus materials were created on a Macintosh Quadra 950 computer using Nightingale software (Camporo Icuity Products) and a Korg WFD synthesizer. Digital recordings were made with a Macintosh Quadra 950 computer running Digidesign software.

During the experiment, the digital sound files were played by a Macintosh IIci computer with an Audiomedia II sound card (for 16-bit sound production). The sound was fed through a Denon amplifier (PMA-480R) to two audiological loudspeakers (GSI) located in a large sound-attenuating booth (Industrial Acoustics Co). The loudspeakers were located inside the sound-attenuating booth, one on each side of the infant, who sat on his or her parent's lap across from the experimenter. A chamber containing a toy and lights was located under each loudspeaker. The front of each chamber was smoked Plexiglas, such that the toy was only visible when the lights were illuminated. The lights and a button box were connected to a Strawberry Tree I/O card in the computer through a custom-built interface box.

Stimuli

During consonant trials, a set of four consonant intervals was repeated in random order, with the constraint that no interval could be presented twice in a row. During dissonant trials, a set of dissonant intervals was presented similarly. All tones comprising the intervals were created with piano timbre. The consonant set of intervals consisted of two perfect fifths (A_3–E_4 [220.0–329.6 Hz] and C_4 to G_4 [261.6–392.0 Hz]) and two octaves (C_4–C_5 [261.6–523.3 Hz] and E_4–E_5 [329.6–659.3 Hz]). The dissonant set consisted of two tritones (B^b_3–E_4 [246.9–329.6 Hz] and F_4–B_4 [349.2–493.9 Hz]) and two minor ninths (B^b_3–B_4 [246.9–493.9 Hz] and E_4 to F_5 [329.6–698.5 Hz]). These intervals are similar in size: the tritone is one semitone smaller than the perfect fifth and the minor ninth is one semitone larger than the octave. With octave equivalence, both the consonant and dissonant sets contain 4 different notes, A C E G and B^b B E F, respectively. Further, the range is identical (19 semitones) in both cases. In terms of pitch height, infants would be expected to prefer the dissonant set, if anything, as it is slightly higher (1 semitone), and has a slightly higher average pitch. The two sets differ in that the notes of the consonant set are all members of one key, that of C major, whereas two keys are needed to encompass the four notes of the dissonant set. However, adults tend to hear the consonant set as going between two keys, C major and A minor. In any case, infants of this age do not appear to have knowledge of key structure (Trainor & Trehub, 1992), so it is unlikely that this difference could influence their preferences. Each interval was repeated in a rhythmic pattern (onset-to-onsets of 600, 300, 300, 600 ms; see Figure 1). Rhythmic

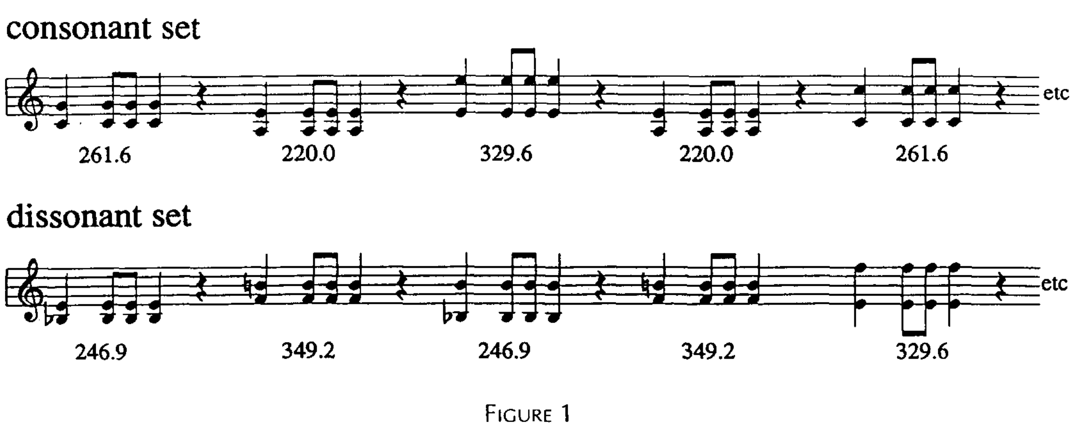

FIGURE 1
Sample excerpts based on the consonant (upper panel) and dissonant (lower panel) sets from Experiment 1. Numbers under the notes indicate the fundamental frequencies.

patterns were separated by 600 ms. Longer notes were 500 ms and shorter notes were 200 ms. Intervals were presented at approximately 60 dB(A) at the location of the infant's head.

Procedure

A preference procedure was modified from that of Fernald (1985), whereby infants controlled the amount of time that each of the consonant and dissonant versions were sounded through their looking behavior. Each infant was tested individually, sitting on their parent's lap facing the experimenter. When the infant was looking forward (i.e., at the experimenter), the experimenter pressed a button on the box connected to the computer to begin the first trial. This caused the lights to flash in the chamber on one side of the infant, revealing a toy. When the infant turned to look at the illuminated toy, the experimenter pressed a second button that caused the lights to remain on and the set (consonant or dissonant) for that trial to begin playing. The music (and lights) remained on until the infant looked away for at least two seconds (all controlled by computer). Twenty trials of the consonant and dissonant sets alternated, as did side of presentation, so that for each infant the consonant set was always played from one side and the dissonant set from the other. The initial set (consonant or dissonant) and the initial side of presentation was counterbalanced across infants. The parent and experimenter listened to masking music through headphones, and were not aware of which set was being presented on which side for each infant.

RESULTS AND DISCUSSION

For each infant, the looking time to the 10 consonant set trials was divided by the total looking time across all 20 trials. The proportion of looking time to the consonant set (M = .60, SD = .12) was significantly greater than the expected chance value of 0.5, $t(11) = 3.06$, $p < .005$ (Figure 2). Eleven of the 12 infants looked longer to produce the consonant set. An ANOVA with proportion looking time to the consonant set as the dependent variable revealed no significant difference across the first 10 versus second 10 trials, as well as no significant effects of which set (consonant or dissonant) or which side (left or right) occurred first. Absolute looking times did decline significantly from the first to the second half of the procedure, $t(11) = 3.87$, $p <$

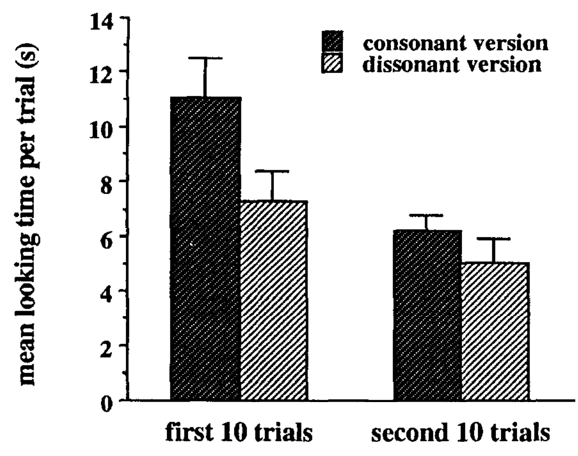

FIGURE 2
Mean looking times (and standard errors) to the consonant and dissonant sets across the first and second halves of Experiment 1.

.002 (mean looking times per trial = 9.2s and 5.4 s for the first and second halves, respectively). Thus, although significant habituation occurred from the first to the second half, the proportion of looking time to produce the consonant version remained similar.

These findings indicate that not only do infants discriminate consonant from dissonant intervals, but, like adults, they prefer to listen to consonant intervals. In Experiment 2, the question of whether this preference for consonance would generalize to a more naturalistic context was tested. Specifically, we modified a Mozart minuet to produce versions with predominantly consonant or predominantly dissonant intervals. In both versions, however, the sense of the phrasing and general structure of the piece remained intact as the rhythmic, durational, and pitch contour information was preserved.

EXPERIMENT 2

Method

Participants

The participants were 16 infants (7 female, 9 male) between 5 months 21 days and 6 months 25 days (*M* = 6 months 10 days) who met the same criteria as those of Experiment 1. A further 5 infants were excluded, 1 for failing to turn his or her head and 4 because of fussing. As in Experiment 1, there was no difference in performance between males and females.

Apparatus

The apparatus was identical to that of Experiment 1.

Stimuli

The stimulus was a simple minuet in C major by Mozart, K. # 1f (see Figure 3). Two 30-second versions were digitally generated with piano timbre. The consonant version was played as written. In the dissonant version, all Gs were changed to G♭s and all Ds to D♭s. This had the effect of creating many dissonant intervals, including many tritones and minor ninths. For each subsequent trial of each version, the music began where it had left off in the previous trial. The tempo (120 quarter notes per min.) and intensity (approximately 60 dB(A)) were identical across the two versions.

With the dissonant modification, the piece is no longer clearly in a key, which would have consequences for adults' perception in terms of *musical* consonance. As defined above, the perception of musical consonance depends on the context in relation to one's knowledge of the musical structure of the idiom, in this case, Western musical structure. Adults would likely find the violations of key structure in the dissonant version to sound particularly bad. Infants, however, have not yet learned about key structure (Lynch et al., 1990; Trainor & Trehub, 1992), so it is unlikely that the lack of a well-defined key *per se* would affect their perception of the dissonant version. By contrast, infants would be expected to perceive the abundant *sensory* dissonance in the modified version.

RESULTS AND DISCUSSION

The results mirrored those of Experiment 1 (Figure 4). Infants listened significantly longer to the consonant versions, $t(15) = 2.98$, $p < .005$ (mean proportion looking time to the consonant version = .57, $SD = .092$). Twelve of the 16 infants looked longer to produce the consonant version. Again there were no significant effects of initial version (consonant or dissonant), initial side of presentation, or proportion of looking time to the consonant version across the first and second 10 trials, although absolute looking times decreased significantly from the first 10 to the second 10 trials, $t(15) = 3.62$, $p < .001$ (mean looking times per trial = 9.7 s and 7.4 s, respectively).

FIGURE 3
The original consonant (upper panel) and dissonant (lower panel) versions of the Mozart minuet used in Experiment 2.

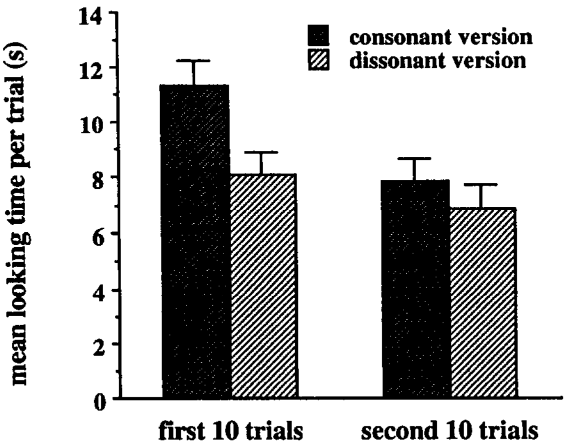

FIGURE 4
Mean looking times (and standard errors) to the consonant and dissonant versions across the first and second halves of Experiment 2.

Thus, infants' preference for consonant over dissonant intervals remained even in a musical context with coherent rhythmic, durational, and pitch contour structure. This finding implies that consonance is highly salient to infants.

GENERAL DISCUSSION

Infants preferred to listen to consonant over dissonant intervals. Given the relation between looking times and affective responses (e.g., Langlois et al., 1990; Werker & McLeod, 1989), it can be concluded that infants, like adults, have an affective preference for consonance. Because 6-month-old infants do not yet have knowledge of musical scale structure (Lynch et al., 1990; Trainor & Trehub, 1992), emotional reactions to music cannot arise in an identical manner in infants and adults (Meyer, 1956). Thus it is particularly interesting for the study of the origins of emotional responses to music that infants show similar affective reactions to those of adults to consonance and dissonance. It indicates first of all that infants have affective responses to an aspect of musical pitch structure early in life. It also indicates that the consonance/dissonance dimension is very basic to musical processing.

It remains an open question whether 6-month-old infants' preference for consonance is a direct consequence of auditory system structure or whether it is learned early in life through exposure to sounds in the natural environment. Western music, particularly children's music, contains predominantly consonant intervals. Thus, infants have had considerably more exposure to consonant than to dissonant intervals. Zajonc and his colleagues (e.g., Zajonc, Crandall, Kail, & Swap, 1974) have demonstrated that adults' affective ratings of stimuli increase with exposure. It is possible that infants' preference for consonance is also an effect of exposure.

Although the prevailing view in musical aesthetics is that a moderate degree of deviation from expectancies based on prototypicality is preferred over complete predictability or a high degree of unpredictability (e.g., Berlyne, 1974), both musically untrained listeners and undergraduate music majors prefer simple, highly prototypical chord sequences over more complex sequences, even though they rate the latter as more interesting (Smith & Melara, 1990). If infants' preference for consonance over dissonance is learned and is a function of familiarity, familiarity may play a similar role in both infants' and adults' emotional reactions to music. On the other hand, preference for consonance may be a consequence of the physiological structure of the auditory system. Adults and infants may prefer the musically familiar because it also tends to be the more consonant. An innate preference for consonance would also account for the predominance of consonant intervals across musical systems. Whatever the basis of infants' preference for consonance, the crucial result is that even though infants do not yet have the musical-system-specific knowledge of scale structure that is involved in adults' emotional reactions to music, infants are similar to adults in their evaluative reactions to consonance and dissonance.

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