Infants' discrimination of happy and sad music

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ABSTRACT

Infants can detect information specifying affect in infant- and adult-directed speech, familiar and unfamiliar facial expressions, and in point-light displays of facial expressions. We examined 3-, 5-, 7-, and 9-month-olds' discrimination of musical excerpts judged by adults and preschoolers as happy and sad. In Experiment 1, using an infant-controlled habituation procedure, 3-, 5-, 7-, and 9-month-olds heard three musical excerpts that were rated as either happy or sad. Following habituation, infants were presented with two new musical excerpts from the other affect group. Nine-month-olds discriminated the musical excerpts rated as affectively different. Five- and seven-month-olds discriminated the happy and sad excerpts when they were habituated to sad excerpts but not when they were habituated to happy excerpts. Three-month-olds showed no evidence of discriminating the sad and happy excerpts. In Experiment 2, 5-, 7-, and 9-month-olds were presented with two new musical excerpts from the same affective group as the habituation excerpts. At no age did infants discriminate these novel, yet affectively similar, musical excerpts. In Experiment 3, we examined 5-, 7-, and 9-month-olds' discrimination of individual excerpts rated as affectively similar. Only the 9-month-olds discriminated the affectively similar individual excerpts. Results are discussed in terms of infants' ability to discriminate affect across a variety of events and its relevance for later social-communicative development.

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Human infants are active participants in social-communicative events with their caregivers from a very young age (Gibson & Pick, 2000; Rochat, Querido, & Striano, 1999). Caregivers' affective expressiveness can foretell of nurturing and soothing or discomfort and distress. Perceiving affective expressiveness directed toward oneself is an important achievement and infants begin to develop sensitivity to vocal as well as facial expressiveness within their first year. Four-month-old infants, for example, can discriminate happy, sad, and angry expressions when presented bimodally (facially and vocally); by 5 months, infants can discriminate among happy, sad, and angry unimodal vocal expressions, and by 7 months of age infants can discriminate happy, sad, and angry unimodal facial expressions (Flom & Bahrick, 2007; Walker-Andrews & Grolnick, 1983; Walker-Andrews & Lennon, 1991). Seven-month-olds also perceive the intermodal correspondence of affective expressiveness conveyed asynchronously facially and vocally (Soken & Pick, 1992; Walker-Andrews, 1986).

Caregivers' communicative intentions to soothe, elicit attention, or to maintain their infants' positive affect are reflected in their speech intonation patterns, e.g., differential pitch contours (Stern, Spieker, & MacKain, 1982). Infant-directed speech or "motherese," differs from ordinary adult-directed speech in a variety of structural properties including its exaggerated prosodic markings, repetitive intonational structures, slower tempo, higher pitch, wider pitch range, more variable funda-

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mental frequency range, and longer pauses (Cooper & Aslin, 1994; Fernald, 1989; Fernald & Cummings, 2003; Fernald & Kuhl, 1987; Grieser & Kuhl, 1988).

Trainor, Austin, and Desjardins (2000) noted that the acoustic characteristics of infant-directed speech include many of the same characteristics of what others have labeled "affectively expressive speech" (see also Kitamura & Burnham, 1996, 1998). Moreover, it has been suggested that it may not be the specific acoustic properties associated with infant-directed speech that is in itself important; rather it is that speech directed toward infants is generally characterized by an overall positive affective expressiveness. Related to the idea of affective expressive speech, Singh, Morgan, and Best (2002) independently manipulated affective expressiveness (happy, neutral, sad) and speech register (infant- or adult-directed speech) and assessed 6-month-olds' preferences for infant- and adult-directed speech. The infants did not distinguish adult-directed from infant-directed speech when the overall affect was controlled. Further, the infants preferred adult-directed but happy expressive speech compared to infant-directed but neutral speech. Thus, infants' preference for infant-directed speech may be due to the general, positive affective expressiveness in speech (Singh et al., 2002).

In addition to speech, infants the world over hear music, participate in musical games in the course of interacting with caregivers, and music also appears to influence infants' behavior (e.g., Behrens & Green, 1993; Cunningham & Sterling, 1988; Terwogt & Van Grinsven, 1991). For example, Rock, Trainor, and Addison (1999) observed that 6-month-olds listening to songs sung in lullaby style behaved differently than when listening to the same songs sung in the style of a play song. Specifically, infants vocalized more during the lullabies than during the play songs and they attended to caregivers somewhat more during the play songs than during the lullabies.

A widespread assumption about music is that it, like speech, has affective connotations and can convey emotion. It has been argued that music attempts to mimic those acoustic properties of speech that are associated with affect or emotion (Davies, 2001; Gabrielsson & Juslin, 2003; Juslin & Laukka, 2003). For example, adults' rating of happiness in music is associated with major mode and faster tempos whereas adults' rating of sadness in music is associated with minor modes and slower tempos (Balkwill & Thompson, 1999; Gabrielsson & Juslin, 1996; Helmholtz, 1954; Hevner, 1937; Peretz, Gagnon, & Bouchard, 1998). An early study of children's judgments of musical affect found that 5-year-olds' judgments, reliably matched adults' ratings of musical excerpts as happy, sad, and angry (Cunningham & Sterling, 1988). The investigators however, could not establish whether children were using tempo, mode, pitch or some other acoustic attribute in making their judgments. Kastner and Crowder (1990) found that 3-year-olds judged affect in musical excerpts on the basis of mode. Other researchers have found that by 5 years of age children rate happy and sad musical excerpts using tempo, and that 6–8-year-olds simultaneously used both tempo and mode in rating happiness and sadness in music (Dalla Bella et al., 2001). Finally, just as infants are sensitive to a variety of acoustic features of speech associated with affect infants are also sensitive to a variety of acoustic features of music that are likewise associated with affect. For example infants discern changes in pitch (Trainor & Trehub, 1992; Trainor & Zacharias, 1998; Trehub, Bull, & Thorpe, 1984), tempo and timbre (Baruch & Drake, 1997; Trainor, 1996), and rhythm (Trehub & Thorpe, 1989).

Based on the review above, (1) there is evidence that infants are sensitive to and can discriminate a variety of acoustic properties of speech and music associated with affect, (2) there is evidence of agreement between adults and pre-schoolers affective judgments of musical excerpts (i.e., happy and sad), and (3) these judgments are associated with the tempo and mode of the musical excerpts (see also Gabrielsson & Juslin, 1996; Kratus, 1993; Pignatiello, Camp, Elder, & Rasar, 1989). The focus of this investigation is infants' ability to discriminate musical excerpts that adults and preschoolers have rated as happy or sad.

Two prior investigations of infants' discrimination of musical excerpts rated happy and sad have yielded inconclusive results. In the first, Gentile (1998) familiarized 8-month-olds to several happy faces and several musical excerpts that adults and preschoolers had judged as happy. Following familiarization infants were presented with test trials in which the faces, the music, or both the faces and music changed from happy to sad—also defined by adults' and preschoolers' judgments. Infants' looking times to the faces decreased when sad music, sad faces or both sad faces and sad music were presented, suggesting they discriminated the musical excerpt types. However, preferential looking at the happy faces might also have been the basis for the pattern of results.

In a second study, Nawrot (2003), using an intermodal-matching paradigm, presented infants between 5 and 9 months of age with two side-by-side dynamic facial expressions (one conveying happiness and the other sadness) while infants heard a musical excerpt defined as happy or sad. The infants looked longer toward a happy face when hearing happy music; however, infants did not differentiate the happy and sad faces when hearing sad musical excerpts. Also, there was limited reliability in adults' and children's prior judgments of the excerpts as happy and sad, rendering interpretation of the results ambiguous.

The purpose of the current study was to assess infants' discrimination of musical excerpts previously judged by adults and young children to be happy and sad. Note that the issue of whether infants perceive affect in music, or experience affective states while listening to music is *not* under investigation here. Rather, the question of interest and study is a logically prior issue of whether infants distinguish between groups of excerpts rated by child and adult listeners as "happy" and "sad". In Experiment 1 we used an infant-controlled habituation procedure to familiarize infants to three musical excerpts that adults and preschoolers have reliably (>80% agreement) judged as happy or sad. Following habituation infants received two new musical excerpts from the other affect group. In Experiment 2 we assessed whether infants in Experiment 1 were habituated to what was common across the three musical excerpts of habituation or to the individual excerpts. In Experiment 3 we assessed infants' discrimination of individual excerpts from the same affect group.

1. Experiment 1

1.1. Method

1.1.1. Participants

Ninety-six infants, 24 at each of the four ages, 3-, 5-, 7-, and 9-months participated. The mean age of the 3-month-olds (13 females and 11 males) was 106 days ($SD = 2$). The mean age of the 5-month-olds (15 females and 9 males) was 152 days ($SD = 3$). The mean age of the 7-month-olds (12 females and 12 males) was 224 days ($SD = 4$) and the mean age of the 9-month-olds (14 females and 10 males) was 267 days ($SD = 6$). The data from 25 additional infants were excluded from the study. Sixteen infants (five 3-month-olds, four 5-month-olds, three 7-month-olds, and four 9-month-olds) were excluded for excessive fussiness. Five infants (three 3-month-olds, one 5-month-old and one 7-month-old) were excluded for equipment failure. Three infants (two 3-month-olds and one 7-month-old) were excluded for failure to habituate or excessive fatigue (see Section 1.1.5 for details). One 5-month-old was excluded for experimenter error. Parents of the participants were initially contacted by telephone. Ninety-seven percent of the participants were White not of Hispanic origin, 2% were Asian, and 1% were Pacific Islanders. All were healthy, normal, full-term infants weighing at least 5 pounds at birth, with 5-min Apgar scores of 7 or higher.

1.1.2. Musical events

Ten musical excerpts (five happy and five sad) were used. Excerpts were selected from among those reliably rated as happy or sad by adults and pre-school aged children (see Gentile, 1998 for details). Briefly, Gentile (1998) asked 24 adult volunteers, who were not musical experts, did not play a musical instrument and were not trained as vocalists, to indicate whether each of twenty-six 60-s musical excerpts were happy, sad, angry or fearful. In order for an excerpt to be categorized as happy, sad, angry or fearful, Gentile (1998) required that at least 80% of the adults label it as conveying the same affect. Following this procedure, 8 of the 26 musical excerpts were rated by adults as happy and five as sad. In addition, adults rated 1 of the 26 excerpts as angry and three as fearful. In a follow-up procedure Gentile (1998) asked 45 children between 3- and 5-years of age to rate 11 excerpts as either happy or sad. The excerpts were the five rated by adults as sad, and six (of the eight) rated by adults as happy. The children pointed toward one of two schematic faces (i.e., a smiling or frowning face) after listening to each excerpt. The ratings of the children generally paralleled those of the adults. The 10 excerpts used in this study (five happy and five sad) are listed in Table 1 along with their respective ratings of happiness or sadness by the adults and children. Seven of the musical excerpts are classical music, two are jazz, and one is a vocal lullaby.

Table 1 also presents the mean tempo, primary mode and meter, as well as the average pitch and pitch range for each musical excerpt. The purpose behind this acoustic description is to provide some measure of the various structural features that are hypothesized to influence ratings of affect in music. In general, the happy excerpts (compared to the sad excerpts) had faster tempos, higher overall pitches, and a greater pitch range. In contrast, the excerpts rated sad had slower tempos, lower overall pitches, and decreased pitch variability.

For each excerpt we extracted the first 20 s and looped it three times creating a 1 min excerpt. We chose the first 20 s because preliminary data with adults and preschoolers revealed that they made their affective ratings within the first 20 s of hearing the excerpt. In addition when an excerpt was presented on any trial it always began at its initial starting point or "time zero." Thus for each excerpt on every trial the musical excerpt always began at the same place.

In addition to the musical excerpts, color video displays of one male and one female adult were also created. The actors were Caucasian and in their early 20's. The male actor had dark hair and the female actor had light hair. The displays depicted the face and shoulder area of the actors who posed a static, affectively neutral expression against a uniform blue background. This static expression was looped creating a 7-min event for each actor. There was an additional film of a plastic green and white turtle whose front legs spun and produced a whirring sound and was used during the first and final control trials.

1.1.3. Apparatus

The 10 musical excerpts were written to a CD and each track was adjusted such that they were presented at the same volume (65 dB as measured from the infant). The visual events (static and affectively neutral faces) were presented with an edit controller and an audio–video matrix switcher that was connected to four video decks. The video decks were connected to a 20-in. (48 cm) color video monitor. Musical excerpts were presented by a CD player connected to stereo system and a speaker located on top of the video monitor.

Infants were seated in an infant seat facing a video monitor from a distance of 50 cm. The monitor was surrounded by a three-panel wood frame covered in black cloth that prevented the infant from seeing the observer. The observers were unaware of the hypotheses of the experiment, were unable to view the visual event, and wore headphones that played music loud enough to mask the music being heard by the infants. The observers monitored infants' visual fixations by depressing a button while the infant fixated on the event and released it while the infant looked away. The button box was connected to a computer programmed to record visual fixations online, and to signal to an experimenter who controlled the presentation of the video displays. The observations of the primary observer controlled the presentation of the stimuli and the observations of the second observer were used in assessing interobserver reliability.

Table 1
Acoustic properties and percent agreement for adults and preschoolers affective ratings of the musical excerpts

Happy excerpts	Primary mode	Meter	Mean pitch and range (in Hz)	Tempo (in bpm)	Adults ratings	Child ratings
Bach: Brandenburg Concerto #3 (First movement)	Major	Triple (6/8)	410 (241–607)	Dotted quarter note = 81	95	92
Beethoven: Symphony #9 (4th movement)	Major	Duple (4/4)	390 (255–565)	Quarter note = 139	90	90
Vince Guaraldi Trio: Linus and Lucy	Major	Duple (4/4)	490 (300–512)	Quarter note = 160	87	84
Preservation Hall Jazz Band: Tiger Rag	Major	Duple (4/4)	470 (269–639)	Quarter note = 113	82	83
Stavinsky: Petrushka	Major	Duple (4/4)	400 (264–559)	Quarter note = 100	81	80
Average			432	118.6	87	85.8

Sad excerpts	Primary mode	Meter	Mean pitch and range (in Hz)	Tempo (in bpm)	Adults ratings	Child ratings
Fauré: Élégie	Minor	Duple (4/4)	420 (206–598)	Quarter note = 63	94	92
Greig: Aase's Death (from Peer Gynt)	Minor	Duple (4/4)	300 (298–432)	Quarter note = 48	89	87
Beethoven: Symphony # 7 (2nd movement)	Minor	Duple (4/4)	300 (232–413)	Quarter note = 73	84	84
Hoist: Venus	Major and minor, although tonic chord is minor	Duple (4/4)	410 (261–507)	Quarter note = 58 ad lib	80	83
Fait Dodo	Major	Duple (4/4)	320 (241–338)	Quarter note = 62 ad lib	80	78
Average			350	60.8	85.4	84.8

Mean acoustic properties and percent agreement for adults and preschoolers affective ratings of the 10 musical excerpts.

1.1.4. Counterbalancing

Half of the infants at each age (n = 12) saw the female actor and half saw the male actor during habituation. Half of the infants at each age who saw the female actor heard happy music (n = 6) during habituation and the other half heard sad music during habituation. The face did not change from habituation to test. This same counterbalancing was used for those infants who saw the male actor.

Given the five happy and five sad excerpts we created "five trios" of excerpts such that across all trios each excerpt occurred once as the first habituation trial, once as the second habituation trial, and once as the third habituation trial (habituation trios ABC; BCD; EAB; DEA; & CDE). At each age four of the five trios were used five times during habituation with the exception that one trio was used four times during habituation. In counterbalancing the excerpts used during the test trials a similar process was used. We created "five pairings" of happy and sad excerpts such that each excerpt occurred once as the first test trial and once as the second test trial (i.e., test trial pairings 1, 2; 2, 3; 3, 4; 4, 5; & 5, 1). Infants were randomly assigned to receive one of the five trios of musical excerpts for habituation and one of the five pairings of musical excerpts from the other affective group during the test trials.

1.1.5. Procedure

Infants participated in an infant-controlled habituation procedure (Horowitz, Paden, Bhana, & Self, 1972) and were habituated to three musical excerpts rated as happy or sad, accompanied by a static affectively neutral face of one of the two actors. Following habituation, infants received three no-change posthabituation trials and then received two infant-controlled test trials in which two new musical excerpts were presented from the other affect group. Infants' discrimination was assessed by visual recovery to these two test trials compared to the no-change posthabituation trials. Infants' looking toward a static face was the measure of attention to the musical excerpt. The pairing of an auditory event with a static, affectively neutral, and non-changing visual display has been used previously in our own research, as well as the research of others in assessing infants' discrimination of auditory events (see Bahrick, Flom, & Lickliter, 2002; Flom & Bahrick, 2007; Horowitz, 1975; Walker-Andrews & Grolnick, 1983; Walker-Andrews & Lennon, 1991).

Each habituation sequence consisted of at least six infant-controlled habituation trials (two for each musical excerpt) and was terminated once the infant reached the habituation criterion and completed three no-change posthabituation trials. A trial began when the infant looked toward the video display and ended when the infant looked away for longer than 1.5 s. Sixty seconds was set as the maximum trial length and 20 was the maximum number of trials. The habituation criterion was established as a 50% decline in looking, on two consecutive trials, compared to the infant's average looking time on the first two trials (i.e., baseline trials). The posthabituation trials established a more conservative habituation criterion taking into account spontaneous regression toward the mean (see Bertenthal, Haith, & Campos, 1983, for discussion of regression effects in habituation designs). These trials also served as a basis for assessing visual recovery. Prior to beginning the habituation sequence, the control event (toy turtle) was presented as a warm-up trial and it was also used after the presentation of the test trials to examine infants' level of fatigue.

We examined each infant's data to determine whether two criteria had been met (see Bahrick, 1992, 2001; Flom & Bahrick, 2007). First, to ensure that infants actually habituated we compared infants' mean posthabituation looking to their initial baseline looking. If an infant's mean posthabituation looking was equal to or greater than their *initial* looking (baseline), this indicated the habituation trials had no effect on the infant's final level of looking, it was judged the infant had not habituated, and the data were excluded from the analyses. It is worth noting, however, if infants' looking during the posthabituation trials exceed the *final two* habituation trials (i.e., they spontaneously regressed) they were not excluded; infants were only excluded using this criterion if their looking exceeded the first two or baseline trials. The data for one 3-month-old and one 7-month-old infant were excluded (see Section 1.1.1) for failure to habituate.

Second, to exclude the data of infants who were overly fatigued and unable to show visual recovery, we compared infants' looking on the first and final control trials (i.e., the moving turtle). On the final control trial, infants were required to look at least 20% of their initial looking level. The data for one 3-month-old was excluded for failure to meet this criterion.

For 44 of the 96 infants (46%) a second observer was present. Interobserver reliability was calculated by a Pearson product moment correlation between the observations of the primary and secondary observers and averaged r = .96 (SD = .04).

1.2. Results and discussion

The primary dependent variable was infants' looking time as a function of trial type (baseline, posthabituation, and test). Infants' looking times for each trial type and age are presented in Table 2 along with infants' visual recovery (the difference in looking between the posthabituation and test trials).

A repeated measures analysis-of-variance was performed with age (3-, 5-, 7-, and 9-month-olds) and music of habituation (happy and sad) as the between subjects factors and trial type (baseline, posthabituation, and test) as the repeated measure. Results revealed significant main effects of trial type, F (2, 176) = 196.8, p < .001, η_p^2 (effect size, partial eta squared) = .78), age, F (3, 88) = 7.7, p < .001, η_p^2 = .40, a significant age by trial type interaction, F (6, 196) = 9.9, p < .001, η_p^2 = .58, and a significant trial type by habituation condition interaction, F (2, 196) = 3.31, p = .039, η_p^2 = .37. A series of Scheffe's post hoc comparisons explored the main effect of trials and revealed across all ages the overall amount of looking for the baseline trials differed from that of the posthabituation trials (p < .001), indicating that infants of all ages habituated to the musical excerpts. The

Table 2

Infants' mean visual fixation (and standard deviations) as function of trial type, infants' average looking across all trial types, and infants' mean visual recovery across ages and experiments

	Experiment 1, affectively different excerpts				Experiment 2, affectively similar excerpts			Experiment 3, individual excerpts		
	3-Months	5-Months	7-Months	9-Months	5-Months	7-Months	9-Months	5-Months	7-Months	9-Months
Baseline	34.0 (14.1)	22.3 (14.2)	18.9 (14.6)	14.7 (8.4)	21.5 (10.3)	16.6 (7.3)	12.5 (4.1)	30.7 (20.4)	13.7 (11.5)	11.2 (10.7)
Posthabituation	6.4 (4.3)	5.1 (2.4)	4.6 (2.8)	3.3 (2.2)	4.1 (2.8)	3.7 (2.1)	2.9 (1.4)	3.8 (2.5)	3.5 (4.1)	1.9 (1.5)
Test	6.7 (5.0)	8.0 (6.1)	7.3 (4.4)	6.6 (2.9)	3.2 (1.2)	3.6 (2.4)	3.4 (2.3)	3.6 (2.4)	3.3 (2.2)	3.5 (1.7)
Visual recovery	.30 (4.5)	2.9* (5.6)	2.7* (5.0)	3.3** (3.2)	−.86 (2.2)	.10 (2.6)	.50 (1.9)	−.2 (1.9)	−.2 (2.6)	1.6** (1.2)

Note: Baseline is the mean visual fixation during the first two habituation trials and reflects initial interest. Posthabituation is the mean visual fixation to the no-change trials just after the habituation criterion was met, and reflects final interest in the habituated events. Test is the mean visual fixation during the two change test trials, and visual recovery is the difference between visual fixation during the test trials and visual fixation during the posthabituation trials.

* $p < .05$.
** $p < .01$.
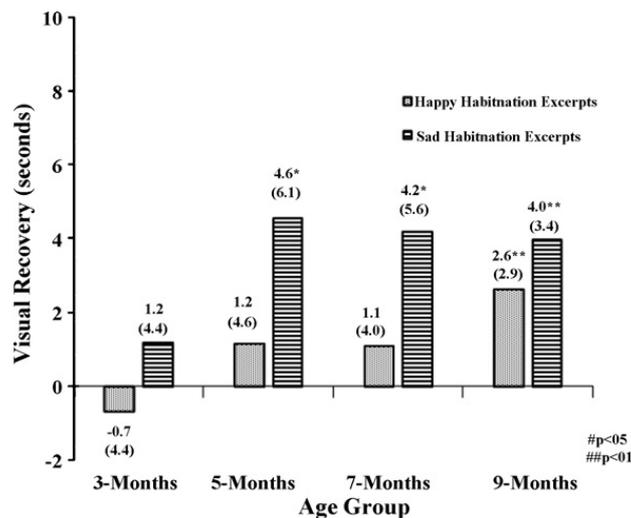
Fig. 1. Mean visual recovery (and standard deviations) as a function of music received during habituation for across age.

main effect of age revealed that the overall looking of the 3-month-olds was greater than that of the 7- and 9-month olds ($p < .01$) but not that of the 5-month-olds ($p > .1$). In general, the fact that younger infants looked longer than older infants is consistent with prior findings (e.g., Fagan, 1974; Hale, 1990; Rose, 1983; Rose, Feldman, & Jankowski, 2002).

In order to address the main research question, whether infants detected a change in type of musical excerpt, Scheffe's post hoc comparisons explored the trial by age interaction. Specifically, we assessed whether infants increased their looking from the posthabituation to the test trials. Results indicate that at all ages, except 3 months ($p > .1$), infants significantly increased their looking from the posthabituation to the test trials, $t(23) = 2.53$, $p = .019$; $t(23) = 2.59$, $p = .016$; $t(23) = 5.1$ $p < .01$, for 5-, 7-, and 9-month olds, respectively. In addition, the results of a one-way ANOVA with age as the between subjects factor, and visual recovery (difference between posthabituation and test trial) as the dependent variable, revealed that 3-month-olds' mean visual recovery significantly differed from that of the 5-, 7- and 9-month-olds, $F(3, 92) = 8.4$, $p < .05$, $\eta_p^2 = .61$, and the visual recoveries of the 5-, 7-, and 9-month-olds did not reliably differ ($p > .1$). This result means that infants at all ages, except 3-month-olds, reliably discriminated between happy and sad musical excerpts and is consistent with the age by trial type analysis-of-variance described above.

In order to more carefully assess infants' discrimination of happy and sad music we examined the significant trial type by music of habituation interaction, $F(2, 196) = 3.31$, $p = .039$, $\eta_p^2 = .37$. Specifically we are interested in whether infants' visual recovery at each age exceeded chance as a function of whether they received happy or sad music during habituation. At 3-months, the mean visual recovery to happy ($M = -.70$; $SD = 4.4$) as well as to sad excerpts ($M = 1.2$; $SD = 5.7$) did not reach significance, (both p's $> .1$). At 5 and 7 months, however, infants who received sad music during habituation (i.e., happy music during test) had visual recoveries that exceeded chance ($M = 4.6$, $SD = 6.1$; $t(11) = 2.7$, $p = .02$; $M = 4.2$, $SD = 5.6$; $t(11) = 2.2$, $p = .02$) for both ages, respectively. The 5- and 7-month-olds who received happy music during habituation (and thus received sad music during the test trials), had visual recoveries ($M = 1.2$, $SD = 4.6$; $p > .1$; $M = 1.1$, $SD = 4.0$; $p > .1$) that while positive, and in the appropriate direction, did not exceed chance. In other words 5- and 7-month-olds showed reliable discrimination when habituated to sad music but not when habituated to happy music. Nine-month-olds who were habituated to sad music ($M = 4.0$, $SD = 3.4$; $t(11) = 4.3$, $p < .01$) as well as those habituated to happy music ($M = 2.6$, $SD = 2.9$; $t(11) = 3.1$, $p = .01$) had visual recoveries that exceeded chance. Fig. 1 below displays infants' visual recovery to a change in musical excerpts based on the music of habituation.

We also examined 3-month-olds' visual recovery to the final control trial (i.e., the spinning turtle). This analysis is relevant in order to rule out the possibility that their lack of visual recovery to a change in the musical excerpts from habituation to test could be attributed to fatigue. Three-month-olds, showed a significant increase in looking to a change in event from the posthabituation trials to the final control trial, $t(23) = 8.03$, $p < .001$. Thus it seems unlikely that the 3-month-olds' lack of apparent discrimination was a result of fatigue.

Using a two-tailed non-parametric binomial test we examined whether the results for each age group were representative of the pattern of individual infants' responses or whether they were driven by a few infants with large positive visual recoveries. At 3 months of age 12 of 24 infants had positive visual recoveries ($R = -11.8 - 11.1$) $p = 1.0$. At 5-months, 15 infants had positive visual recoveries ($R = -4.3 - 19.4$) $p = .307$. Of the twelve 5-month-olds habituated to sad music, and hearing happy music during the test trials, 10 had positive visual recoveries ($R = -1.6 - 19.4$) $p < .05$. At 7-months, 15 of 24 infants had positive visual recoveries ($R = -4.6 - 13.8$) $p = .307$ and of the twelve 7-month olds habituated to sad music 11 had positive visual recoveries ($R = -4.6 - 13.3$) $p < .01$. At 9-months 22 of 24 infants had positive visual recoveries ($R = -4.3 - 10.2$) $p < .001$. Thus, data at the individual infant level converge with findings of group analyses and demonstrate clear evidence of discriminating musical excerpts differing in judged affect by 9-months of age, with 5- and 7-month-olds doing so only when habituated to sad music.

Because the amount of time infants attend to a habituation event is an important basis for discrimination, a one-way ANOVA was conducted to determine whether infants differed in their time to reach habituation. Results revealed a non-significant effect ($p > .1$). Thus, while the younger infants' (3- and 5-month-olds) initial baseline looking was greater than that of the 9-month-olds, infants did not differ across ages in terms of the overall processing time during the habituation procedure. We will return to this issue in Section 4. Finally we examined whether there were any effects of actor or musical excerpt on infants' visual recovery. Results of these analyses did not reach significance, $F(1, 94) = .62$, $p = .78$; $F(4, 91) = 1.2$, $p = .31$.

The results of Experiment 1 demonstrate that by 9-months of age infants discriminate musical excerpts rated as happy (or sad) from excerpts rated as sad (or happy) and that 3-month-olds do not. Five- and seven-month-olds reliably discriminated between the excerpt groups when they were habituated to sad music, but not when they were habituated to happy music. The basis of this order effect is not clear. It may be that the happy music is more arousing and thus elicits renewed looking after habituation. It might also be that the 5- and 7-month-olds do discriminate sad from happy music after habituation to sad music, but their discrimination is masked by their inattentiveness or avoidance of sad events (cf. Soken & Pick, 1999; Flom & Pick, 2005). This issue will also be taken up in Section 4.

A question raised by the results of Experiment 1 is whether the older infants' discrimination was among individual excerpts, or whether their discrimination was based on the differences between the excerpts rated happy and those rated sad. In other words, did the infants in Experiment 1 renew their looking because they heard new musical excerpts or because the excerpts were from different rated affect groups (happy and sad)? The purpose of Experiments 2 and 3 was to address this question by assessing infants' visual recovery to new test excerpts from the same affective group as those presented during habituation.

2. Experiment 2

The purpose of Experiment 2 was to assess whether infants show visual recovery to new musical excerpts rated as the same affect as those heard during habituation. In the first experiment it is possible that infants renewed looking on the test trials because the musical excerpts were novel excerpts and not because the excerpts were rated as affectively different. In Experiment 2, as in Experiment 1, infants were habituated to three different musical excerpts (same musical excerpts used in Experiment 1) and following habituation infants received two new musical excerpts from the same affective group as those heard during habituation. If infants show reliable visual recovery to the new excerpts that are similar to those of habituation it would question any claim that infants are discriminating musical excerpts across the happy and sad distinction. Three-month-olds were not included in this experiment because they did not show significant visual recovery in Experiment 1.

2.1. Method

2.1.1. Participants

Twenty-four infants at 5-, 7-, and 9-months of age participated. The mean age of the 5-month-olds (12 females and 12 males) was 149 days ($SD = 4$). The mean age of the 7-month-olds (14 females and 10 males) was 224 days ($SD = 3.5$) and the mean age of the 9-month-olds (9 females and 15 males) was 269 days ($SD = 7.0$). Thirteen additional infants participated; however, their data were excluded from the final analyses. The data from eight infants (four 5-month-olds, three 7-month-olds and one 9-month-old) were excluded from the final analyses due to fussiness. Two 5-month-olds were excluded for experimenter error. One 7-month-old was excluded for failure to habituate in 20 or fewer trials and two 5-month-olds were excluded for fatigue. Ninety-nine percent of the participants were White not of Hispanic origin and 1% were Asian. All were healthy, normal, full-term infants weighing at least 5 pounds at birth, with 5-min Apgar scores of 7 or higher. Parents of the participants were initially contacted by telephone.

2.1.2. Music excerpts, counterbalancing, apparatus, and procedure

All musical excerpts, apparatus, and other procedures were identical to Experiment 1 except during the test trials where infants heard two new musical excerpts that were from the same affect group as those heard during habituation. For 28 of the 72 participants (39% of the sample) a second observer was present. Interoberserver reliability between the primary and secondary observers averaged $r = .94$ ($SD = .07$) in Experiment 2.

2.2. Results and discussion

As in Experiment 1 the primary dependent variable was infants' looking time as a function of trial type (baseline, posthabituation, and test). Infants' looking time for each trial type and age is presented in Table 2 and infants' visual recovery is presented in Fig. 1. As in Experiment 1 an overall repeated measures ANOVA with age (5-, 7-, and 9-months) as a between subjects factor, and trial type (baseline, posthabituation, and test) as the repeated measure, was performed to compare looking behavior across age and trial types. Results revealed a significant main effect of age, $F(2, 69) = 8.6$, $p < .01$, $\eta_p^2 = .52$, a significant main effect of trial type, $F(2, 138) = 184.0$, $p < .001$, $\eta_p^2 = .86$, and a significant age by trial type interaction, $F(4,$

138) = 13.6, $p < .01$, $\eta_p^2 = .74$. The main effect of age was that, for all trial types, younger infants looked longer than the older infants. Scheffe' post hoc comparisons indicate that 5-month-olds, on average, looked longer than either the 7-month-olds ($p = .02$) or the 9-month-olds ($p < .01$), and that the looking times of the 7- and 9-month-olds did not significantly differ ($p > .1$).

Comparisons regarding the main effect of trial type indicate that infants looked longer during the baseline trials ($M = 15.3$; $SD = 9.2$) than during either the posthabituation ($M = 3.6$; $SD = 2.2$) or the test trials ($M = 3.4$; $SD = 2.0$). In addition, the overall mean looking for the posthabituation trials and the test trials did not differ statistically ($p > .1$). Thus, across all ages, infants showed evidence of habituation from baseline to posthabituation and did not renew looking from the posthabituation trials to the test trials.

We also examined the significant age by trial type interaction and found that the mean looking for baseline trials differed significantly as a function of age; the baseline looking of the 5-month-olds was reliably longer than that of the 7- and 9-month-olds, $t(46) = 2.7$, $p = .01$; $t(46) = 5.0$, $p < .01$, respectively. Second, we found that infants did not increase their looking from the posthabituation trials to the test trials at any age (all p's > .1). In addition, the results of a one-way ANOVA with age as the between subjects factor and visual recovery as the dependent variable, $F(2, 69) = 2.19$, $p = .120$, $\eta_p^2 = .06$, failed to reach significance (see Fig. 1). Thus in Experiment 2 the age by trial type interaction is a result of an age effect of longer looking during the baseline trials, and at no age did infants increase their looking from the posthabituation to the test trials.

In Experiment 2, regardless of whether infants were habituated to excerpts rated happy or sad, infants failed to show reliable discrimination when presented two new excerpts from the same affect group. This pattern of results suggests that the infants in Experiment 1 who renewed looking during test trials did so because the test excerpts were from the different affect group from those heard during habituation and not simply because they were novel excerpts. In a final experiment we wanted to assess at what age(s) infants would discriminate the individual excerpts. This experiment is important because if we are to claim that by 9-months of age infants discriminate musical excerpts on the basis of adults' and children's affect rating, then it is important to document that infants can discriminate individual excerpts that received the same affective rating. Otherwise, infants' generalization of habituation to excerpts from the same affect group in Experiment 2 might simply reflect insensitivity to differences among individual excerpts.

3. Experiment 3

The purpose of Experiment 3 was to assess whether infants between 5 and 9 months of age discriminate individual musical excerpts with the same affect rating by adults and preschoolers. In Experiment 3 infants were habituated to one musical excerpt and following habituation each infant received two infant-controlled test trials with one new musical excerpt with the same affect rating as the excerpt of habituation. If infants in Experiment 3 show reliable discrimination of individual excerpts from the same affect group, then infants' lack of discrimination in Experiment 2 of excerpts from the same affect group is not a result of their inability to discriminate individual excerpts.

3.1. Method

3.1.1. Participants

Thirty-six infants between 5 and 9 months of age participated. The mean age of the 5-month-olds (seven females and five males) was 153 days ($SD = 3$). The mean age of the 7-month-olds (five females and seven males) was 227 days ($SD = 3.5$) and the mean age of the 9-month-olds (nine females and three males) was 273 days ($SD = 5.2$). Seven additional infants (three 5- and 7-month-olds) were excluded for fussiness. The data for four infants (one 5- and three 9-month-olds) were excluded for experimenter error. Three 7-month-olds were excluded from the final analyses for equipment failure. Ninety-two percent of the 36 participants ($N = 33$) were White not of Hispanic origin. Six percent were Pacific Islanders and 2% were Asian. All were healthy, normal, full-term infants weighing at least 5 pounds at birth. Parents of the participants were initially contacted by telephone.

3.1.2. Music excerpts, counterbalancing, apparatus, and procedure

In Experiment 3 we used the same excerpt pairings as for the test trials in Experiment 1 (pairings 1, 2; 2, 3; 3, 4; 4, 5; & 5, 1). For the happy excerpts one infant at each age received one of the four pairings and two infants received a fifth pairing. For the other six infants at each age a similar counterbalancing process was used for the sad excerpts. All apparatus and other equipment was the same as previous experiments. Infants were habituated to a single musical excerpt rated as either happy or sad. Following habituation, and the two no-change posthabituation trials, infants received two test trials. During the two test trials infants were presented with one new musical excerpt that was rated as affectively similar to the excerpt of habituation. For 18 of the 36 participants (50% of the sample) included in the final analyses a second observer was present. Interoberserver reliability between the primary and secondary observers averaged $r = .95$ ($SD = .11$) in Experiment 3.

3.2. Results and discussion

Infants mean visual fixation as a function of trial type (baseline, posthabituation, test) for infants in each age group is presented in Table 2. As in previous experiments an overall repeated measures analysis of variance with age (5-, 7-, and

9-months) as a between subjects factor, and trial type (baseline, posthabituation, and test) as the repeated measure, was performed to compare looking behavior across age and trial types. Results revealed a significant main effect of age, F (2, 33) = 5.28, p = .01, $\eta_p^2 = .24$, a significant main effect of trial type, F (2, 66) = 41.5, $p < .001$, $\eta_p^2 = .56$ and a significant age by trial type interaction, F (4, 66) = 6.2, $p < .01$, $\eta_p^2 = .27$. The main effect of age demonstrates that, across all trial types, younger infants looked longer than the older infants. Scheffe's post hoc comparisons for the main effect of age indicate that 5-month-olds, on average, looked longer than the 7-month-olds (p = .045) as well as the 9-month-olds (p = .012). The 7- and 9-month-olds did not significantly differ ($p > .1$). Follow-up comparisons regarding the main effect of trial type indicate that across all ages, infants looked longer during the baseline trials (M = 18.5; SD = 16.9) than the posthabituation (M = 3.1; SD = 2.9), t (35) = 5.9, $p < .001$, or test trials (M = 3.5; SD = 2.1), t (35) = 5.5, $p < .001$.

Scheffe's post hoc comparisons were use to examine the interaction and revealed that only the 9-month-olds showed a significant increase in their mean looking from the posthabituation trials to the test trials (M = 1.64; SD = 1.2), t (11) = 3.51, $p < .01$. The increase in looking from posthabituation to test trials did not differ for either the 5- or 7-months-olds ($p > .1$). The results of the interaction also revealed that the mean looking during baseline trials differed as a function of age such that the baseline looking of the 5-month-olds reliably differed from that of the 7- and 9-month-olds, t (22) = 2.5, p = .02, t (22) = 3.0, $p < .01$, respectively. Thus, infants at all three ages showed evidence of habituation, only the 9-month-olds showed a significant increase in looking from the posthabituation trials to the test trials (i.e., discrimination), and 5-month-olds looked longer during the first two trials compared to the 7- and 9-month-olds.

A one-way ANOVA comparing infants' visual recovery by age (5-, 7-, and 9-months) was also significant, F (2, 33) = 4.6, $p < .05$, $\eta_p^2 = .12$, indicating 9-month-olds mean visual recovery (M = 1.64; SD = 1.2) differed from that 5- and 7-month-olds (M = −.20; SD = 1.9; M = −.20; SD = 2.6), respectively (see Fig. 1). We also assessed whether there was any difference in 9-month-olds' visual recovery as a function of whether they received happy or sad musical excerpts, the mean visual recovery for 9-month-olds in the happy and sad conditions did not reliably differ, t (10) = .112, $p > .1$. Five- and seven-month-olds' discrimination of individual excerpts did not exceed chance in the happy or sad condition (all p's > .1) and their visual recoveries for the happy and sad conditions did not reliably differ at 5- or 7-months of age (all p's > .1). Thus the 9-month-olds in Experiment 3 discriminated the individual exemplars within the broad based happy and sad categories, and their visual recoveries did not differ as a function of whether they heard happy or sad musical excerpts. These results support the claim that 9-month-olds' failure to discriminate the new musical excerpts that were affectively similar to those of habituation (Experiment 2), is not a result of their insensitivity to differences among individual excerpts.

4. General discussion

The present study examined infants' discrimination of musical excerpts rated by adults and preschoolers as happy and sad . In Experiment 1, following habituation to three affectively similar excerpts, 9-month-olds renewed looking when they heard music excerpts from the other affective group. Five- and seven-month-olds discriminated happy from sad musical excerpts when they heard sad excerpts during habituation, but not when they heard happy excerpts during habituation. Finally, under no condition did 3-month-olds in Experiment 1 discriminate happy and sad music.

In Experiment 2 at no age did infants show significant discrimination when hearing two new excerpts from the same affect group as their habituation excerpts. In Experiment 3, only the 9-month-olds demonstrated sensitivity to differences among individual excerpts from the same affect group. Together, these results provide the first compelling evidence that by 9 months, infants discriminate happy and sad music—as defined by adults' and preschoolers' ratings (cf. Gentile, 1998; Nawrot, 2003). The findings are also congruent with previous research assessing infants' discrimination of various acoustic properties of music often associated with affect or emotion. For example, young infants show a preference for higher compared to lower pitched singing (Trainor & Zacharias, 1998), and a preference for music that is consonant compared to dissonant (Trainor & Heinmiller, 1998; Trainor, Wu, Tsang, & Plantinga, 2002) where higher pitch and consonance are both features correlated with adults' positive emotional judgments of music (Juslin & Laukka, 2003; van de Geer, Levelt, & Plomp, 1962).

Unfortunately the results for the 5- and 7-month-olds do not afford clear interpretation. One possible explanation for the asymmetrical discrimination pattern shown by these infants in Experiment 1 is that the music rated as happy may be more arousing and may elicit renewed looking following habituation to sad music whereas presenting music rated as sad is not as arousing following habituation to happy music. Similarly, 5- and 7-month-olds may differ in their "responsiveness" or reaction to happy and sad music. It is well established that infants of this age range frequently reduce their looking when presented with sad vocal and/or facial expressions (e.g., Flom & Pick, 2005; Gentile, 1998; Soken & Pick, 1999; Termine & Izard, 1988).

A possible explanation for some of the 5- and 7-month-olds results in Experiment 3 may have to do with their differential familiarity with sad and happy facial and vocal expressions. Specifically, they may have had less experience with sad communicative and social interactions and this limited experience may attenuate their discrimination of sad musical excerpts. One possibility for future research might include examining infants of depressed mothers. Because infants of depressed mothers have had more experience with "sad" or affectively "flat" communicative interactions and these interactions influence a variety of social and cognitive factors in infancy (e.g., Field, 1994; Field, Diego, Hernandez-Reif, Schanberg, & Kuhn, 2003), these interactions may also enhance infants' discrimination of music—particularly for sad musical excerpts.

A different basis for the ambiguity of the 5- and 7-month-olds' results may be in the habituation procedure itself. In our procedure, as in most other contemporary applications of the habituation method, the criterion established for habituation was the same across the age ranges observed (i.e., a 50% decrement in infants' looking from baseline). Schöner and Thelen (2006) recently discussed well-documented facts of infants' behavior in habituation situations, including that younger infants habituate more slowly than older infants, and require more trials/time to criterion in order for novelty preferences to emerge. Our younger babies' initial baseline looking times were longer than those of older babies, but the looking times and trials to criterion did not differ. It is possible that the younger babies in our study were not as fully habituated as the older babies when they reached the same (50% decline in looking from baseline) criterion and therefore did not show clear evidence of discriminating the familiar from novel excerpts. This possibility may explain the non-significant discrimination of the 5- and 7-month-olds in Experiment 3 and the asymmetrical discrimination of the 5- and 7-month-olds in Experiment 1. We are currently exploring this possibility by establishing a more conservative criterion of habituation in an effort to bring greater clarity to the 5- and 7-month-olds' behavior. Taken together however, these experiments portray a developmental emergence of discriminating happy and sad musical excerpts during the second half-year of life.

What is the significance of finding that by 9-months of age infants can discriminate musical excerpts rated as happy and sad? Much of the research on infants' perception of music has focused on their sensitivity to specific acoustic properties of music. For example, early research examined infants' discrimination of tempo and of mode, each of which may be related to music characterized as happy or sad (e.g., Hevner, 1937; Kastner & Crowder, 1990; Kratus, 1993; Pignatiello et al., 1989), Our question, however, is a more global one of whether infants can discriminate what others have rated as happy and sad music. Because we asked infants to discriminate musical excerpts at this more global level and, aside from volume, we did not manipulate the acoustic properties of the music; we cannot isolate specific properties infants were responding to. Our interest was in maintaining the integrity of the music they listened to. Finally, as explicitly noted earlier and emphasized throughout, we make no claims about whether infants perceived affect in the music or experienced either happiness or sadness while listening to it.

Infants' discrimination of music is important because music, like speech, is communicative and a basic function of music and speech is to express meaning through emotion (Besson & Schön, 2001; Brown, 2000; Buck, 1984; Scherer, 1995; Trainor, 1996). In terms of infants' perception of speech, much has been done in terms of examining infants' discrimination and preference for infant-directed speech as well as the acoustic and affective properties associated with such speech (Cooper & Aslin, 1990; Fernald, 1984, 1985, 1989, 1992; Papoušek, Bornstein, Nuzzo, Papoušek, & Symmes, 1990; Papoušuek, Papoušek, & Symmes, 1991). Within the domain of music, however, less is known regarding infants' discrimination or perception of affect in music. Unfortunately little empirical work has also addressed the hypothesized relationship between language and music in the communication of emotion (McMullen & Saffran, 2004; Trehub, 2003; Trehub & Trainor, 1993). Finally, the convergence of research on the development of speech perception and discrimination of affective expressiveness in vocalizations, gestures, speech, and music, will further our understanding of early social-communicative development and our general understanding of social and interpersonal development in human infants.

Acknowledgments

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