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The Role of Intersensory Redundancy in the Emergence of Social Referencing in 5 ½-month-old Infants

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Abstract

Early evidence of social referencing was examined in 5 ½-month-old infants. Infants were habituated to two films of moving toys, one toy eliciting a woman's positive emotional expression and the other eliciting a negative expression under conditions of bimodal (audiovisual) or unimodal visual (silent) speech. It was predicted that intersensory redundancy provided by audiovisual (but not available in unimodal visual) events would enhance detection of the relation between emotional expressions and the corresponding toy. Consistent with predictions, only infants who received bimodal, audiovisual events detected a change in the affect-object relations, showing increased looking during a switch test in which the toy-affect pairing was reversed. Moreover, in a subsequent live preference test, they preferentially touched the 3-dimensional toy previously paired with the positive expression. These findings suggest social referencing emerges by 5 ½ months of age in the context of intersensory redundancy provided by dynamic multimodal stimulation and that even 5 ½-month-old infants demonstrate preferences for 3-dimensional objects based on affective information depicted in videotaped events.

Infant responsiveness to others' emotional expressions is a cornerstone of social and cognitive development. Social referencing, a fundamental social cognitive milestone, refers to the ability to perceive the relationship between another's emotional response and the object or event to which it refers, and to subsequently regulate one's exploratory behavior towards the object or event in accordance with the emotional expression (see Campos & Sternberg, 1981; Feinman, 1982; Feinman & Lewis, 1983; Sorce, Emde, Campos, & Klinnert, 1985; Walden & Ogan, 1988). Infants thus learn by observing others' affective responses, moving toward and exploring novel objects which elicit positive emotional expressions and inhibiting exploration of novel objects which elicit negative emotional expressions.

Research demonstrates that infants show reliable evidence of social referencing from about 10 to 18 months of age. They avoid novel or ambiguous objects and events when adults display a fearful expression toward them, and approach when adults display a happy expression (Boccia & Campos, 1989; Feinman, 1982; Feinman & Lewis, 1983; Klinnert, 1984; Klinnert, Emde, Butterfield, & Campos, 1986; Mumme & Fernald, 2003; Walden & Ogan, 1988). However, little research has explored the precursors to this ability in early infancy (but see, Cleveland, Schug, & Striano, 2007; Striano & Bertin, 2005) and thus it is not known when or under what conditions it emerges.

Social referencing involves a variety of complex social-cognitive skills. It requires infants to selectively attend to and perceive another's emotional expression (affect perception), selectively attend to and perceive the object, person, or event to which attention is directed

(object perception), share attention with another person about the object, person, or event (joint visual attention), relate the emotional expression with the object to which it refers (detect affect-object relations), and finally, regulate their behavior towards the object in accordance with the emoter's expression (regulate behavior).

Research indicates that infants show many of these component skills within the first half year of life. Infants can discriminate multimodal (i.e. audiovisual) emotional expressions in familiar adults or contexts by 3 to 4 months of age (Kahana-Kalman & Walker-Andrews, 2001; Montague & Walker-Andrews, 2001), and in unfamiliar adults by 5-7 months of age (Flom & Bahrick, 2007; Walker-Andrews, 1986). In unfamiliar adults, infants first perceive emotional expressions in dynamic audiovisual speech (3 to 5 months), later in vocal expressions alone (5 months), and finally, in facial expressions alone (7 months; Flom & Bahrick, 2007; see Walker-Andrews, 1997 for a review). Infants show gaze following and sensitivity to triadic interactions by 3 to 6 months of age (Reid, Striano, Kauffman, & Johnson, 2004; Striano & Bertin, 2005; Striano & Stahl, 2005). For example, 3- and 6-month-olds gazed longer and smiled more at an experimenter in both dyadic and triadic (experimenter, infant, and toy) contexts, when she coordinated visual attention and affect between an object and the infant than when she did not (Striano & Stahl, 2005). Further, infants of 4- and 6-months look more towards objects that are the focus of an adult's gaze (Morales, Mundy, & Rojas, 1998; Reid & Striano, 2005). Thus, by the first half year of life, infants detect and discriminate several emotional expressions, follow another's direction of gaze, even within a triadic context, and demonstrate sensitivity to coordinated visual attention and affect during a joint attention episode, all fundamental skills underlying social referencing.

Social referencing has typically been studied in somewhat older infants. Studies have assessed infant regulation of exploratory behavior towards ambiguous or novel objects or events such as toys, a stranger, or a visual cliff, as a function of an adult's positive versus negative emotional expression (Campos & Sternberg, 1981; Feinman & Lewis, 1983; Hertenstein & Campos, 2004; Kim, Walden, & Knieps, 2010; Klinnert, Emde, Butterfield, & Campos, 1986; Moses, Baldwin, Rosicky, & Tidball, 1996; Mumme, Fernald, & Herrera, 1996; Sorce, Emde, Campos, & Klinnert, 1985). These studies find reliable evidence of social referencing after 11-12 months of age. Only a few studies have tested younger infants. Walden and Ogan (1988) found evidence of behavioral inhibition toward toys following expressions of fear at 10-22 months but not at 6-9 months in live interactions, and Mumme and Fernald (2003) found evidence of behavioral inhibition at 12 but not 10 months of age following televised audiovisual expressions of fear. The youngest infants to show behavioral regulation thus far appear to be 8 ½- to 10-month-olds (Boccia & Campos, 1989). They were less friendly toward strangers following expressions of worry than happiness in live interactions. It is not yet known how younger infants would perform in social referencing tasks. Social referencing tasks often require infants to locomote towards (or away from) the referent object, making it difficult to assess pre-locomotor infants (under 7 or 8 months of age). Detection of affect-object relations and perhaps regulation of behavior in accordance with such relations may thus develop earlier than social referencing studies suggest when using measures of exploration such as reaching or touching, particularly in familiar, dynamic, multimodal contexts.

Most social events occur in dynamic, multimodal contexts (involving visual, auditory, and tactile stimulation) with affective expressions conveyed by synchronous faces and voices. The intersensory redundancy hypothesis (IRH; Bahrick & Lickliter, 2000, 2002), a theory of selective attention, makes clear predictions regarding the contexts that promote development of affect perception and social referencing. Perception of affect is based on amodal information such as rhythm, tempo, duration, and intensity patterns. According to the IRH,

affect perception should emerge first in dynamic, multimodal stimulation (e.g., audiovisual speech), where detection of amodal information is promoted (Bahrick & Lickliter, 2002, 2004; Bahrick, Lickliter, & Flom, 2004). Later in development, as infants become more experienced perceivers, perception of affect should extend to unimodal (visual or auditory) stimulation. This developmental progression was supported by recent research findings (Flom & Bahrick, 2007) which demonstrated that by 4 months of age, infants discriminated affective expressions in multimodal (audiovisual) but not unimodal (auditory or visual) speech. However, by 7 months, infants discriminated the same expressions in both unimodal and multimodal speech. Similarly, Walker-Andrews (1997) concluded from a systematic review of the developmental literature, that emotion perception emerged first in multimodal stimulation and later extended to unimodal stimulation. Thus, multimodal, dynamic stimulation likely provides the earliest context in which social referencing emerges.

A few studies have examined the role of multisensory information in infants' social referencing. For example, 12-month-old, but not 10-month-old infants differentially looked at and touched objects that were referenced with a positive expression as opposed to a negative or neutral expression by an actress in a multimodal (audiovisual) televised presentation (Mumme & Fernald, 2003). Similarly, Hertenstein & Campos (2004) found that 11- and 14-month-old infants who viewed live multimodal affective expressions directed towards toys, inhibited play with toys paired with negative as compared with positive expressions, even after a delay of 3 minutes or 1 hour (11- and 14-month-olds, respectively). Vaish & Striano (2004) assessed the role of facial and vocal cues in social referencing in 12-month-olds. While looking at a visual cliff, mothers conveyed happy affect using multimodal (facial and vocal expressions), unimodal visual (facial only), and unimodal auditory (vocal only) expressions. Infants crossed the visual cliff in all conditions but crossed faster and looked longer towards their mothers in multimodal and unimodal auditory (vocal expression) conditions. The authors concluded that by 12 months of age, the voice alone was sufficient for social referencing.

Additionally, Flom (in press) assessed 12-month-old infants' detection and memory for affect-object relations when the affective expressions were conveyed by faces and voices (multimodal). Infants were able to detect a change in the affect-object pairing and showed memory for this pairing by preferentially looking at the toy paired with the positive expression up to 1 day later if the experimenter's gaze had been directed toward the object. However, infants showed no evidence of memory for the affect-object pairing if the experimenter's gaze had been directed away from the object. Thus, multimodal presentation of affective expressions as well as gaze congruence with the direction of the referent object, provide important contexts for infants' perception of affect-object relations. Unlike most previous studies (Vaish & Striano 2004 is an exception), the present study examined the contribution of multisensory information to infants' detection of affect-object relations and their preferences for objects paired with positive expressions by comparing infants' performance under multimodal and unimodal visual conditions.

Although previous studies provide important information about infants' social referencing skills in unimodal and multimodal contexts, it is not known when social referencing emerges and what conditions promote its development. To this end, the present study assessed the early emergence of social referencing in 5 ½-month-old infants. Infants' ability to relate two toys with the emotional expressions they elicited in an actress was examined in bimodal (audiovisual speech) and unimodal (visual speech) contexts. Subsequently, infants' touching preferences for the toys was measured. The present study differed from prior studies by testing younger infants and combining, in a single design, several conditions thought to maximize the opportunity for social referencing. First, consistent with predictions of the IRH, it was expected that redundancy between the face and voice in multimodal speech

would facilitate social referencing over unimodal visual stimulation. Thus, to test this hypothesis, both unimodal and multimodal conditions were included. Second, an infant-control habituation procedure was used, providing longer exposure times (averaging between 2- and 4-minutes for dynamic events, see Bahrick & Gogate, 2001; Bahrick, Hernandez-Reif, & Flom, 2005) to the affect-object pairings than is typical for social referencing tasks in the literature (30 seconds; Hertenstein & Campos, 2004; and 20 seconds Mumme & Fernald, 2003; Vaish & Striano, 2004). Third, the objects used were colorful toys that moved and were designed to engage young infants' attention. And finally, the actress highlighted the affect-object relations by making her gaze and expressions contingent upon movements of the toys, likely maximizing infants' attention to the affect-object relations. Each time the toy moved she gazed at the toy, responded with an affective expression then looked at the camera (infant) and back to the toy again.

Contingencies between behaviors and environmental events provide powerful and salient information about the temporal, spatial, and causal relations among events. Perception of contingency is critical for infants' developing communication skills, sense of competence and agency, and ability to predict others' behavior (Bigelow & DeCoste, 2003; Gergely & Watson, 1999; Harrist & Waugh, 2002; Sullivan, Lewis, & Allesandri, 1992; Tarabulsey, Tessier, & Kappas, 1996; Watson, 1972). Contingent events are highly salient to young infants and promote the development of social cognition (Rochat & Striano, 1999). By 3- to 5-months, infants can detect the temporal and spatial contingencies provided by video feedback from their own leg and arm movements (Bahrick & Watson, 1985; Rochat & Morgan, 1995; Schmuckler, 1996). Young infants are also sensitive to contingency in face-to-face interactions (Beebe, Jaffe, Markese, Buck, Chen, Cohen, Bahrick, Andrews, & Feldstein, 2010; Bigelow & DeCoste, 2003; Bigelow, MacLean, & McDonald 1996; Hains & Muir, 1996; Harrist & Waugh, 2002) and prefer contingent over noncontingent responses (Murray & Trevarthan, 1985; Bigelow & Birch, 1999). Young infants can also detect environmental contingencies including forming spatio-temporal expectations by anticipating the timing, location, and appearance of briefly presented images (Haith, Hazan, & Goodman, 1988; Haith & McCarty, 1990; Wentworth & Haith, 1992). In the present study, we created events depicting the natural contingent structure between actions of objects and the contingent gaze and affective expressions they elicited in order to maximize infant attention to the relationship between the emotional expressions and the toys.

The present study explored the multimodal origins of social referencing in 5 ½-month-old infants. It posed two research questions. First, would bimodal audiovisual stimulation (which provides intersensory redundancy) enhance young infants' ability to relate affective expressions with moving toys, to a greater extent than unimodal visual stimulation (which provides no intersensory redundancy)? If so, infants habituated with audiovisual (but not unimodal visual) films of an actress responding with positive affect to the movements of one toy and with negative affect to the movements of another toy should show significant visual recovery to a change in affect-object pairing during the test trials. And second, would infant detection of affect-object relations in videotaped events translate to infant behavioral regulation with respect to the 3-dimensional toys? If so, following bimodal audiovisual habituation (but not unimodal visual habituation) infants should show a preference for manipulating the toys that had been previously paired with the positive expression during the habituation phase. This would illustrate that perception of affect-object relations translates to appropriate exploratory behavior toward the object, the essence of social referencing.

Method

Participants

Thirty-two 5 ½-month-old infants (19 males and 13 females) with a mean age of 169 days ($SD = 5.2$) participated. All infants had a gestational age of at least 38 weeks and Apgar scores of at least 9 (out of 10). Twenty-eight infants were Hispanic, 3 were Caucasian, and 1 was African American. Ten additional infants participated but their data were excluded due to excessive fussiness ($N=2$), experimenter error ($N=1$), failure to meet the fatigue criterion (looking at the control stimulus for at least 20% of initial looking time, $N=3$), and failure to habituate within twenty trials ($N=4$).

Stimuli and Apparatus

Two toys served as stimulus objects for the study, a robot and a pony. The 3-dimensional toys were used for all preference tests whereas videos of the affect-object events were used for the habituation phase. Four filmed events were created depicting each toy moving across a surface eliciting a happy/excited or a fearful/avoidant affective expression from an actress (see Figure 1). Each film consisted of 30-second clips that looped and each 30-second clip depicted 5 instances of the affective expressions and 5 toy movements. The actress's gaze and expressions were contingent on the movements of the toy so that each time the toy moved and made its characteristic sounds, the actress responded by suddenly looking at the toy, turning back to the camera and saying, "Look it moves. Oh, it moved!" using either a happy/excited or a fearful/avoidant facial and vocal expression. The toy pony moved forward and bobbed its head while naying. The toy robot moved forward and intermittently opened its arms while making a mechanical clicking noise. Only the surface of the table, the toy, and the head and shoulders of the actress were visible to maximize infants' attention to the affect-object relations (see Figure 1). The pony and robot toys were of similar sizes (7.2×6.2 inches and 4.8×5.8 inches, respectively), but differed in shape and color/pattern. One version of the filmed events was bimodal (audiovisual), depicting the natural synchrony between sights and sounds. Another version of the events was unimodal (visual) and was created by removing the soundtrack.

During the habituation phase, infants were seated in an infant seat on top of a table facing two 19-inch television monitors, approximately 22 inches away. The monitors were surrounded by black poster board with two apertures from which observers could record the infants' visual fixations using joy sticks connected to a computer that recorded and computed the duration of visual fixations to the displays and signaled another experimenter as to when to commence and terminate each trial. A camera (Sony Digital Handycam Model no. DCR-TRV30) recorded the infants' facial expressions during the habituation phase. During the manual preference test, the 3-dimensional toys were placed on a tray in front of the infant and the camera recorded infants' manual exploration of the toys for subsequent coding.

Procedure

The procedure consisted of an initial visual preference pre-test with the 3-dimensional toys, followed by an habituation and switch test with the filmed events, followed by a visual preference post-test, and finally a manual preference test with the 3-dimensional toys (see Table 1). Infants were randomly assigned to the bimodal or unimodal visual conditions ($n=16$ each). The two conditions were identical except that the audiovisual filmed events were used in the habituation and the test phases of the bimodal condition, whereas the unimodal visual (silent) events were used during the habituation and test phases of the unimodal condition. By removing the soundtrack for the unimodal condition, the

intersensory redundancy created by the synchronous visual and auditory stimulation was eliminated.

Visual preference pre-test—Parents were asked if their infant had ever seen either of the two toys and all reported they had not. Infants were presented with the two 3-dimensional toys to assess baseline preferences. They were seated on a table top and held by an experimenter (blind to the hypotheses of the study). A second experimenter, on the right side of the infant, placed the robot and pony toys side by side on a tray covered with a black cloth. Then, the infant was turned to face the toys, the experimenter uncovered the toys, walked behind the infant, and two 10-s trials began. The toys remained on the tray directly in front of the infant and out of reach during the two test trials. The experimenter covered the toys with the black cloth for a few seconds in between trials while their lateral positions were switched, and then uncovered the toys and the second trial commenced. The lateral positions of the toys were also counterbalanced across infants so that half the infants viewed the toy pony on the right and the robot on the left and half viewed the opposite arrangement first. Infants' looking times to the toys were measured.

Habituation and switch test—Approximately 1 minute after the pre-test, infants participated in an infant-control habituation procedure where they had the opportunity to learn to relate each emotional expression (e.g. happy/excited vs. negative/fearful) with a particular toy (e.g. robot vs. pony). Learning was assessed in the test trials where the relation between the toy and affective expression was switched. During habituation, half the infants viewed the pony eliciting the actress' happy/excited expression and the robot eliciting the fearful/avoidant expression, whereas the other infants received the opposite pairing. The pony paired with one expression and the robot paired with another expression were shown on alternating trials. Half the infants received the pony first and the robot toy second in the alternating pattern and half received the opposite order. Infants viewed the alternating films for a minimum of 6 and a maximum of 20 infant-controlled trials. Each trial was presented until the infant looked away for at least 1.5 s or the trial reached the maximum of 60 s. A 2-second inter-stimulus interval (ISI) followed the end of each trial during which a black screen was displayed. The average of the infants' looking times to the first two trials (baseline) was calculated. Once the infant decreased his or her looking time to the films by at least 50% of baseline for two consecutive trials, they were considered to have habituated to the events.

After the habituation criterion was met, infants were presented with two additional no-change post-habituation trials followed by two switch test trials. Visual recovery was calculated by subtracting looking time to the test trials from looking to the no-change post-habituation trials (see Bahrick, 1992; Bahrick, Hernandez-Reif, & Flom, 2005; Flom & Bahrick, 2007). In order to ensure that infants had actually habituated, their looking time to the post-habituation trials was compared with that of the habituation criterion. If post-habituation looking was not less than criterion, infants were re-habituated, receiving additional habituation trials until the habituation criterion was reached again (4 of the 32 infants were re-habituated). Then, the two no-change post-habituation trials were repeated. This ensured that all infants had habituated to the two events before being presented with the test trials. Two test trials depicting a switch in the affect-object relations were presented. For example, if an infant had been habituated to the pony eliciting a happy/excited expression and the robot eliciting a fearful/avoidant expression, then the test trials depicted the robot eliciting the happy/excited expression and the pony eliciting the fearful/avoidant expression. It was expected that if infants had detected and learned the relation between the toy and the affective expression, they would show a significant visual recovery to the switch in the affect-object pairing during the test trials. Trained observers unaware of the infant's

condition and unable to see the events on the monitor recorded infants' visual fixations. Inter-observer reliability was obtained for 25% of the participants.

Visual preference post-test and manual preference test—Following the habituation phase, infants were again presented with the 3-dimensional toys. An experimenter placed the toys side by side on a tray approximately 17 cm in front of the infant for two 10-s trials (identical to the visual preference pre-test) and infants' looking to both toys was measured. Then, the experimenter covered the toys with a black cloth for a few seconds, switched their lateral positions, pushed the tray toward the infant so that the toys were within reach, and uncovered the toys to begin the first manual preference test trial. Infants were given two 30-s trials to touch and explore the 3-dimensional toys. After the first manual preference test trial, the experimenter again covered the toys with the cloth and switched their lateral positions before presenting the second manual preference test trial. Infants' number of touches to the toys as well as the amount of time spent touching each toy was measured from the video-taped recordings and served as the dependent variables.

Results

Visual Preference Pre-test

Infants' looking preferences to the toy robot and pony were measured and inter-observer reliability between trained observers was calculated for 25 percent of the participants using a Pearson product-moment correlation. Inter-observer reliability averaged .92 ($SD = .04$). To determine whether infants showed a significant preference for the toys prior to the habituation phase, a single sample t -test was conducted on the proportion of total looking time (PTLT) to each toy against the chance value of .5. Results revealed no significant preference ($M = .52$, $SD = .19$, robot; $M = .48$, $SD = .19$, pony, $t(31) = 0.94$, $p > .1$, $\eta^2 = .03$). Right and left looking preferences were also tested and revealed no significant effect ($M = .52$, $SD = .16$, right side, $M = .48$, $SD = .12$, $t(31) = .98$, $p < .1$, $\eta^2 = .03$).

Habituation and Switch Test

Although infants were filmed during the habituation phase for later coding of affective expressions, few displayed detectable affective expressions and thus no analyses were performed. Infants' looking times for each trial type (baseline, post-habituation, test trials, and visual recovery to the change in affect-object pairing) and condition (bimodal vs. unimodal visual) are presented in Table 2. Inter-observer reliability between trained observers was calculated for 25 percent of the participants for looking time to the habituation and switch test events using the Pearson product-moment correlation. Inter-observer reliability averaged .99 ($SD = .01$).

In order to address the main research question, under what conditions, if any, did infants detect the switch in affect-object relations, a repeated measures analysis of variance (ANOVA) was performed with condition (bimodal audiovisual vs. unimodal visual) as the between subjects factor and trial type (baseline, post-habituation, and test) as the repeated measure. A significant effect of trial type was found, $F(2, 28) = 19.4$, $p < .01$, $\eta^2 = .58$, and post hoc tests revealed greater looking during baseline than during post-habituation or test ($ps < .01$) and greater looking during test than post-habituation trials ($p < .01$). A significant effect of condition was also found, $F(1, 30) = 16.7$, $p < .01$, $\eta^2 = .36$, with greater looking in the bimodal than the unimodal condition. Most relevant to our research question, a significant trial type by condition interaction was found, $F(6, 29) = 13.05$, $p < .01$, $\eta^2 = .73$ with greater looking during the test trials than during post-habituation trials for the bimodal condition, but not for the unimodal condition.

To further explore the condition by trial type interaction (see Table 2), and to determine under which condition infants detected the switch in affect-object pairing, single sample *t*-tests were used to evaluate visual recovery scores (increase in looking from post-habituation to test). Infants in the bimodal condition showed significant visual recovery ($M = 13$, $SD = 11.26$; $t(15) = 4.8$, $p < .01$, $\eta^2 = .61$) to the change in affect-object relations, whereas those in the unimodal visual condition did not, ($M = 1.1$, $SD = 4.64$; $t(15) = .88$, $p > .05$, $\eta^2 = .05$). Moreover, visual recovery in the bimodal audiovisual condition was significantly greater than that of the unimodal visual condition, $t(30) = 4.1$, $p < .01$, $\eta^2 = .4$. Thus, infants who were habituated to the bimodal audiovisual events showed evidence of detecting the change in affect-object relations while those habituated to the unimodal visual events did not.

Secondary analyses were also performed to assess any differences in interest in the bimodal vs. unimodal events. Two independent sample *t*-tests were conducted to determine whether infants in the bimodal vs. unimodal conditions differed in their initial interest level (baseline), final interest level (post-habituation), or total looking time (number of seconds looking during habituation) to the habituation stimulus events. Results revealed a significant difference in initial interest level, $t(30) = 3.9$, $p < .05$, $\eta^2 = .34$, with infants in the bimodal audiovisual condition ($M = 49.4$, $SD = 10.9$) looking longer initially to the stimulus events than infants in the unimodal visual condition ($M = 29.7$, $SD = 16.5$). However, there was no significant difference in final interest level ($M = 7.7$, $SD = 5.7$, bimodal condition, $M = 6.2$, $SD = 3.5$, unimodal condition) $t(30) = .857$, $p > .1$, $\eta^2 = .09$. or total looking time to the habituation events across conditions, ($M = 302.5$, $SD = 152.1$, bimodal condition, $M = 222.4$, $SD = 157.9$, unimodal condition) $t(30) = 1.9$, $p > .1$, $\eta^2 = .11$.

Visual Preference Post-test

Analyses were identical to those of the visual preference pre-test. Single sample *t*-tests revealed no significant PTLTs for the toy previously paired with the happy expression for infants in the bimodal or unimodal condition ($M = .55$, $SD = .16$, bimodal condition, $M = .56$, $SD = .15$, unimodal condition; $ps > .1$). Further, mean PTLTs were compared for the pre-test vs. post-test and results revealed no significant shift in preference ($M = .03$, $SD = .17$, bimodal; $M = .06$, $SD = .24$, $p > .1$, unimodal; $ps > .1$).

Manual Preference Test

Touces were coded as any manual or oral contact with the toys. On average, infants spent 59% of the total exposure time touching the toys ($M = .60$, $SD = .29$, bimodal audiovisual condition; $M = .58$, $SD = .25$, unimodal visual condition) and on average, touches lasted approximately 1.4 seconds ($M = 1.5$, $SD = 1.7$, bimodal audiovisual condition; $M = 1.3$, $SD = 1.2$, unimodal visual condition). Touching preferences for the toy placed on the right vs. left side were coded. No significant preference for side of presentation was found ($M = .51$, $SD = .18$ for right side).

The proportion of the total number of touches (PTNT) as well as the proportion of total time spent touching (PTTT) the toy previously paired with the happy expression during the habituation phase served as the primary indices of social referencing. PTNT was calculated for each infant by dividing their total number of touches to the toy previously paired with the happy expression by their total number of touches to both toys, and averaging across infants. PTTT was calculated for each infant by dividing the total number of seconds they spent touching the toy previously paired with the happy expression during the habituation phase by the total number of seconds they spent touching both toys, and averaging across infants. To address the main research question, did infants regulate their exploratory behavior toward the three-dimensional objects as a function of the emotional expressions

paired with them during habituation, PTNT and PTTT were evaluated with single sample *t*-tests. Results demonstrated that the mean PTNT for infants in the bimodal audiovisual condition was significantly greater than the chance value of .5 ($M = .62$, $SD = .19$; $t(13) = 2.3$, $p < .05$, $\eta^2 = .3$), but the PTNT for infants in the unimodal visual condition was not ($M = .53$, $SD = .22$; $p > .1$). Further, mean PTTT for infants in the bimodal audiovisual condition was significantly greater than the chance value of .5 ($M = .63$, $SD = .17$; $t(13) = 2.7$, $p < .05$, $\eta^2 = .3$), but the PTTT for infants in the unimodal visual condition was not ($M = .53$, $SD = .2$; $p > .1$). Thus, infants who were habituated to the bimodal audiovisual events showed a significant touching preference for the 3-dimensional toy previously paired with the happy expression during habituation, whereas infants habituated to the unimodal visual events showed no touching preference for either toy.

Discussion

The present study examined the origins of social referencing in 5 ½-month-old infants. Infants' ability to relate an actress's positive vs. negative emotional response to the movements of two novel toys (a pony and a robot) in a bimodal audiovisual or a unimodal visual video presentation was examined. Following habituation to events that paired the positive expression with one toy and the negative expression with the other toy, infants in the bimodal, audiovisual (but not the unimodal visual) condition showed visual recovery to a switch in the affect-object pairing, indicating they detected the change in the object-affect relations. Then, infants' touching preferences for the toys that had previously been paired with the positive vs. negative affective expressions were evaluated to determine if infants used information acquired during habituation to regulate their exploration of the 3-dimensional objects. Results indicated that infants who received bimodal, audiovisual events (but not infants who received unimodal visual events) showed evidence of detecting the affect-object relations and subsequently regulated their manual exploration of the 3-dimensional toys, preferentially touching the toy that had previously elicited a happy expression in the actress. These findings indicate that young infants can detect the relation between an affective response to a moving novel toy and use that relationship to guide their manual exploration of the toys in multimodal, dynamic contexts. This provides the first demonstration of social referencing in infants as young as 5 ½ months of age.

Results were consistent with predictions generated from the IRH (Bahrick & Lickliter, 2000, 2002; Flom & Bahrick 2007). Intersensory redundancy, available in bimodal audiovisual, but not unimodal visual stimulation, highlights attention to and promotes perceptual processing of events and their redundantly specified properties, including affective information in audiovisual speech (Flom & Bahrick, 2007). Consequently, detection of affect emerges first in redundant audiovisual speech contexts and is later extended to unimodal auditory, and finally to unimodal visual contexts (see Flom & Bahrick, 2007). It was thus predicted that infants receiving bimodal, audiovisual stimulation would show enhanced detection of affect-object relations and would subsequently show significant manual preferences for objects previously paired with the positive affective expression, relative to infants receiving unimodal visual stimulation during habituation. The present findings support our predictions and suggest that social referencing and detection of object-affect relations emerge in rich multimodal contexts where attention and perceptual processing of the relations between affective expressions and the events to which they refer is maximized.

The present findings indicate that by 5 ½ months of age, infants showed a variety of perceptual and cognitive skills fundamental to social referencing. They discriminated happy and fearful affective expressions in naturalistic audiovisual facial and vocal stimulation (affect perception). Infants also discriminated two novel toys, differing in color, shape, and

movement (object perception). Moreover, they detected the relation between an affective expression and the object to which it referred in multimodal audiovisual stimulation (detect object-affect relations). They also remembered the affective expressions, the objects, and the relations between them (recall affect-object relations). Finally, infants used their knowledge of the affect-object relations to guide their manual preferences for the toys that had previously been paired with the positive emotional expression in multimodal dynamic displays (regulate behavior).

Although infants did not show preferential looking during the visual preference post-test to the toy previously paired with the positive expression during habituation, they did preferentially touch the toy paired with the positive affective expression. Although infant looking preferences were in the predicted direction, they were characterized by rather high variability (with SDs ranging from .15 to .24). In contrast with manual preferences, looking preferences may be influenced by a greater variety of factors and thus provide more indirect measures of preference. For example, one might look at an aversive or potentially dangerous object, but not approach or touch it. Accordingly, to evaluate the effects of emotional information from others on infant behavior toward objects, the majority of social referencing studies have used more direct measures consisting of infant action toward objects or people.

Interestingly, consistent with predictions, infants demonstrated touching preferences for the toy previously paired with the happy expression during habituation, despite the fact that infants had viewed a brief reversal of this pairing during the switch test that followed. This apparent lack of interference from the switch test on later preferences is consistent with findings from prior studies in which visual preference tests have followed habituation and switch tests (Bahrick & Gogate, 2001; Bahrick, et, al., 2005, Flom & Johnson, in press). This is likely due to the fact that the habituation paradigm allows infants to fully process both events (e.g. robot paired with the happy expression and pony paired with the fearful expression), whereas the exposure to the reversal during the switch test (e.g., robot paired with the fearful expression and pony paired with the happy expression) is relatively brief and occurs after original learning. Thus, in the present study, infants spent an average of 262.4 s ($SD = 172.8$) viewing the events during habituation and only 26.51s ($SD = 24.46$) during the switch test. Apparently, the more extended processing time for affect-object relations during habituation overrides that of the switch test. Information from the switch test is also likely processed in the context of the prior habituation events, since the switch occurred later and would be experienced as more novel when processed in relation to the habituation events. In any case, manual preferences for the object previously paired with the happy expression in the bimodal condition were robust despite infants having seen a brief reversal of this relationship during the switch test.

Why might infants as young as 5 ½ months demonstrate evidence of social referencing in the present study, when prior studies have typically found evidence after 11-12 months (Boccia & Campos, 1989; Campos & Sternberg, 1981; Feinman & Lewis, 1983; Hertenstein & Campos, 2004; Kim, Walden, & Knieps, 2010; Klinnert, Emde, Butterfield, & Campos, 1986; Moses, Baldwin, Rosicky, & Tidball, 1996; Mumme, Fernald, & Herrera, 1996; Sorce, Emde, Campos, & Klinnert, 1985), but no evidence in infants younger than 8 ½ months (Walden & Ogan, 1988). In the present study we maximized the likelihood of eliciting social referencing through a combination of factors. As discussed above, in the bimodal audiovisual condition, intersensory redundancy was provided which maximizes attention to the event, the affective information, and the relation between the two. Successful social referencing was observed only when intersensory redundancy was provided by multimodal stimulation at 5 ½ months of age. In addition, however, there were a number of other variables that were not directly manipulated but that likely contributed to early evidence of social referencing. First, the present study used interesting (colorful, age

appropriate) and engaging novel toys. Second, the toys moved in interesting ways, further attracting infants' attention to the events. These factors, along with complete processing afforded by the habituation paradigm may have made the task easier for young infants. Finally, and perhaps most important, the actress' affective expressions and eye gaze were contingently responsive to the movements of the toys promoting attention to the relation between the affective expressions and the toys. Contingencies are highly salient to young infants (Harrist & Waugh, 2002; Rochat & Striano, 1999), highlighting the relations between the movements of the objects and the contingent affective responses they elicited. Infants are also sensitive to eye gaze direction, and gaze promotes infant attention to objects (Flom & Johnson, in press; Morales, Mundy, & Rojas, 1998; Reid & Striano, 2005). In the present events, the actress' eye gaze shifted to the toy at the onset of its movement and then briefly alternated between the toy and the camera (just after the toy moved) as if looking directly at the participant while vocalizing. For some or all of these reasons, the conditions of the present study elicited evidence of social referencing at 5 ½-months, considerably younger than previously observed.

Exploring conditions that elicit evidence of developmental capabilities earlier than previously found can provide an important avenue for uncovering the basis and fundamental conditions that promote the development of the capabilities in question. The present study demonstrates that intersensory redundancy provided by synchronous audiovisual stimulation (across face, voice, and across the sights and sounds of object motion) constitute one important condition for supporting the development of social referencing. Further research is needed to determine the relative importance of other factors such as contingency, eye gaze direction, and object motion in the emergence of social referencing.

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Figure 1.
Photos of stimulus events used for the habituation and switch test phases.

Table 1

Study Procedure: Trial Structure, Stimuli, Conditions, and Dependent Variables for All Phases

	Phases			
	<u>Visual Preference Pre-test</u>	<u>Habituation & Switch Test</u>	<u>Visual Preference Post-test</u>	<u>Manual Preference Test</u>
Trial Structure	2 10-s trials	6 to 20 infant controlled trials	2 10-s trials	2 30-s trials
Stimuli	3-D toys side by side	Alternating films of 2 toys each paired with 1 affective expression	3-D toys side by side	3-D toys side by side
Conditions	Unimodal visual	Bimodal audiovisual vs. unimodal visual	Unimodal visual	Unimodal visual
Dependent Variables	PTLT to each toy	Visual recovery to switch in affect-object pairing	PTLT to each toy	PTNT & PTTT to toy previously paired with happy affect

Note: PTLT is the proportion of total looking time, PTNT is the proportion of total number of touches, and PTTT is the proportion of total time spent touching the toy paired with happy affect.

Table 2

Means and Standard Deviations for Looking Times in Seconds for Baseline, Post-habituation, Test Trials, and Visual Recovery for Bimodal Audiovisual and Unimodal Visual Presentation Conditions

Trial Type	<u>Bimodal Audiovisual</u>		<u>Unimodal Visual</u>	
	<u><i>M</i></u>	<u><i>SD</i></u>	<u><i>M</i></u>	<u><i>SD</i></u>
Baseline	49.4	10.9	29.7	16.5
Post-habituation	7.7	5.7	6.2	3.5
Test	20.7	9.1	7.3	5.5
Visual Recovery	13*	11.3	1.1	4.6

Note: Baseline is the mean looking time during the first two habituation trials and reflects initial interest level. Post-habituation is the mean looking time during the two no-change trials just after the habituation criterion was met and reflects final interest level for habituation events. Test is the mean looking time during the two switch test trials, and visual recovery is the difference between looking time during the test trials and during the post-habituation trials.

*
 $p < .05$