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The Social Context of Infant Intention Understanding

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Abstract

Traditional looking-time paradigms are often used to assess infants' attention to socio-cognitive phenomena, but the link between these laboratory scenarios and real-world interactions is unclear. The current study investigated hypothesized relations between traditional social-cognitive looking-time paradigms and their real-world counterparts in caregiver-infant social interaction. Seventy-five 10- to 12-month-old infants participated in a structured play session with their caregiver, as well as a traditional looking-time paradigm targeting intentional action. Infants' ability to quickly parse intentional displays correlated with several key qualities of their everyday interactions. In particular, caregiver and infant interaction quality, maternal supportiveness, caregiver and infant joint engagement skill, and social attentiveness in infants correlated with faster habituation to looking-time displays. These results support a linkage between social-cognitive looking-time laboratory paradigms and more naturalistic partner interaction, at this key age. The data both provide external validation for the large body of social-cognitive findings emerging from laboratory looking-time paradigms, and contribute to a growing literature tracking the developmental trajectory of infants' understanding of people over the first two years.

Many researchers now contend that by the end of their first year of life infants come to understand that intentional, or goal-directed, states underlie the actions and expressions of others (Akhtar & Martinez-Sussmann, 2007; Baird & Astington, 2005; Tomasello, et al., 2007). This includes appreciating agents as intentional actors (engaged in deliberate acts like reaching for and getting things) and as intentional experiencers (experiencing states like desires for, emotions about, and perceptions of things). Others contend that initial infant understandings are more teleological and less intentional (Csibra, 2008), but even they argue that these early understandings are crucial for developing intentional understanding in the second year of life. These conclusions rest in part on studies where infants engage in active interaction with others (Carpenter, et al., 2000; Grafenhain, et al., 2009; Saylor, et al., 2007),

but the large majority have used looking-time paradigms where infants look at and react to agents' actions and expressions (e.g., Gergely, Nadasdy, Csibra, & Biro, 1995; Sodian & Thoermer 2004; Woodward, 1998). For example, Phillips, Wellman and Spelke (2002) showed that 12- and 14-month-olds recognized that an actor would intentionally grasp the object that she had visually regarded with positive affect, demonstrating an ability to use information about an adult's direction of gaze and emotional expression to predict action present at the end of the first year of life (see also Moses, et al., 2001; Mumme, et al., 2007). In further clarification of this paradigm, Vaish and Woodward (2010) showed that infants' prediction of an actor's reaching behavior in certain displays depends more on the actor's attentional than emotional cues.

Data such as these now provide the foundation for many theories of social-cognitive development, but there are significant gaps. In particular, little research examines the relationship between social experiences infants might have and their performance on laboratory paradigms for assessing social cognition and particularly intention understanding. Although there is considerable research about the sorts of everyday experiences that impact preschool social cognition (e.g. Astington & Jenkins, 1999; Diesendruck & Ben-Eliyahu, 2006; Ruffman, Slade & Crowe, 2002; Watson, Painter & Bornstein, 2001; Wellman, Lane, LaBounty, & Olson, 2011), only a few scattered infant studies offer insights into the relationships between everyday social experiences and the looking-time laboratory paradigms on which theoretical work so heavily relies.

Recent research has established a link between infant looking-time measures and (later) preschool social cognition (Aschersleben, Hofer & Jovanovic, 2008; Wellman, et al., 2004; 2008; Yamaguchi, et al., 2009), providing some evidence for the connection between children's performance on these limited laboratory tests and their understanding of social relationships. But what about connections to social relationships in infancy itself? In an intriguing initial study, Brune and Woodward (2007) reported that 10-month-olds' responses to a display linking a person's gaze to an intended object was related to their engagement in joint attention during a mother-infant play session. Hofer, et al. (2008) reported that 6-month-olds whose mothers were rated to have a modestly controlling interaction style looked differentially at test displays of intentional action, while those whose mothers were rated as sensitive or unresponsive did not. In an integration of looking-time and attachment research, Johnson and colleagues (2007) showed that securely attached infants (but not insecurely attached ones) looked significantly longer at an animated display in which a large "mother" object appeared to intentionally abandon a smaller "baby" object.

More generally, attachment research provides several candidate constructs that serve to inspire hypotheses linking key social experiences with infants' burgeoning understanding of their social world more broadly, including intention understandings. Thus we know that maternal mind-mindedness (Laranjo, Bernier, & Meins, 2008), the sensitivity of mothers' responses to their infants (Bigelow, et al., 2010; Rosenblum, et al., 2008), and aspects of infant temperament (Belsky & Rovine, 1987) are associated with a secure attachment style. Infant attachment status predicts, and is predicted by, aspects of infant responsiveness to mother's actions, communications, and mother-infant affect attunement (e.g. Beebe, 2010). These findings suggest that the quality of mother-infant interaction could lead to enhanced

social-cognitive understanding of the sort measured in infant laboratory assessments *or* enhanced infant social cognition could lead mothers to refer more often to the infant's internal desires, intentions, emotions and mind. Beyond attachment research, infant temperament additionally seems a good candidate mechanism to consider because an observant, non-reactive temperament at age 3 longitudinally predicts 5-year-olds' theory of mind, measured by false-belief understanding (Wellman, et al., 2011).

Two other relevant social experiences likely play supporting roles in infants' emerging understanding of others as intentional agents: joint attention and imitation. *Joint attention* is a hallmark of early cognitive development in which infants begin to coordinate objects into their previously dyadic social interactions – an ability that entails monitoring another's attentional stance toward the self and the object. Joint attention has long been taken to demonstrate infants' growing socio-cognitive abilities and was related to a looking-time measure in Brune and Woodward (2007). Moreover, joint attention at 20 months is predictive of later preschool-age theory of mind (Charman, et al., 2000). Infant *imitation* also has a long history of being studied as both a precursor to, and result of, increased socio-cognitive competence. Deliberate infant imitation is evident as early as the second half of the first year (see Bauer & Kleinknecht, 2002), and it is related to both infant language development and mother-infant responsiveness (e.g., Masur & Olson, 2008). Indeed, disruptions in both joint attention and imitation are characteristic of toddlers with autism spectrum disorders, known to present in older children as difficulty with theory of mind both in and out of the laboratory (among other difficulties and delays, Baron-Cohen, et al., 1985; Charman, et al., 1998; Smith & Bryson, 1994).

The current research has one primary goal: to investigate links between infant habituation to intentional displays and their concurrent social interactions with a familiar partner. Following the reasoning just outlined, we focused primarily on five key constructs (quality of mother-infant interaction, socially-attentive infant temperament, imitation, joint attention, and maternal-mind mindedness) in relation to infant differences in social-cognitive understanding (as measured in laboratory, looking-time assessments). Because the present research is concurrent, we can discover relations between the laboratory and semi-naturalistic social experiences, but we will be unable to determine the direction of these relations--whether infant social-interactive experiences contribute to enhanced intention understanding, whether enhanced social cognition contributes to infants' social interactions, or (likely) both. Still, such findings would tell us about developmentally important co-relations, and additionally would provide external validity data for the burgeoning number of infant looking-time assessments of social-cognitive understanding. If these laboratory assessments tap important, formative understandings, then they should clearly relate to relevant aspects of infant experience, action, and interaction. If they do not, we are failing to focus on the most telling, useful aspects of infant social cognition in our laboratory research.

In sum, in the present study we report on two tasks implemented concurrently when infants were about 12 months old: (1) a traditional looking-time paradigm in which infants witness intentional action-emotion displays, and (2) a caregiver-infant interaction episode comprised of a free-play interaction and a novel toy teaching interaction. Our aim is to gain insight into

the relation between traditional looking-time paradigms and their counterparts in social interaction.

Method

Overview

Almost 100 10- to 12-month-old infants were seen in a multi-phase research session lasting 40 to 50 minutes. After warm up, the protocol began with a looking-time procedure involving habituation and test trials (from Phillips, Wellman & Spelke, 2002). Caregiver and infant then adjourned to a large playroom housing several toys and furniture where they participated in a 6 minute free play session (only 4 of the caregiver-infant pairs included the father; because 95% of our caregiver sample was mothers we refer to our data as mother-infant data). This was followed by the infant being placed in a high chair for an additional 10 minutes while the mother demonstrated how to manipulate a series of 5 novel small objects.

The looking-time task used first by Phillips, Wellman and Spelke (2002) was chosen because (a) it is representative of those used in assessing intention understanding (e.g., Vaish & Woodward, 2010; Woodward, 2003), (b) involves infant appreciation of both actions (reaching) and emotions (interest), and (c) this same task was used in two prior studies relating looking-time differences to preschool theory of mind (Wellman, et al., 2004; 2008). Thus we know this task yields individual differences measures that sufficiently vary across year-old infants and moreover that relate to at least one other important social-cognitive measure: preschool false-belief understanding.

Free play was chosen because in attachment-related research it yields various measures of mother and infant social-emotional interactions that relate to attachment status. Indeed, prior research has utilized free play codings to yield measures of mother-infant interactions, mind-mindedness, and infant social attentiveness (Hofer, et al., 2008; Kaitz, et al., 2010; Rosenblum, et al., 2008) – our focal factors in the present research. Joint attention measures such as gaze following, pointing, and the like have also been informatively collected from free play situations (Legerstee & Fisher, 2008; Vallotton, 2009). Mother-infant play with toys, and especially adult demonstration of novel toys, is commonly used to code infant object-centered imitation and relatedly mother's imitation of her infant's action.

Any study of this sort must make numerous analysis and coding choices. For example, free play and toy demonstration could yield almost an infinite variety of codable behaviors (e.g., mother yawning, infant object reaching, infant grasping manipulation, infant large motor behavior, etc.). Our analyses are more limited, focusing on the five focal constructs outlined thus far (quality of mother-infant interaction, socially attentive infant temperament, joint-attention, imitation, and maternal mind-mindedness). Clearly, our hypotheses concern specifically social-cognitive understanding and related social-interactive experiences and behaviors. As such, certain other factors hypothetically should not relate to infant social cognition. In the realm of temperament, we included a measure of infant activity level to serve as a discriminant contrast. If activity level predicts looking-time responses, then other links we discover may not be so clearly social-cognitive but instead more domain-general.

Similarly, we included several measures of infant's object-oriented attention and a measure of infant's non-verbal vocalizations (including numerous self-vocalizations) chosen to be generally language-related but not directly social-communicative. Our reasoning here was that infant looking times in object-oriented or perceptual-attention habituation tasks consistently relate to later preschool domain-general cognition as measured by standard IQ tests (e.g., Bornstein & Sigman, 1986; McCall & Carriger, 1993). If our social-cognitive, intention-understanding task predicts variation on object-attention and communicative-fluency measures then it is possible that any additional links we find represent just general infant competence and attention rather than links more specific to social-cognitive understandings and experiences per se.

Studies examining mother-infant free play behavior proceed either by coding highly quantified observational tallies of specific acts (numbers of infant reaches, or points, or mother looks at infant per minute) or more typically by coding global, aggregated categories (Kaitz, et al., 2010; Slaughter, Peterson, & Carpenter, 2008). We concentrated on more global, aggregate codings; others have argued that global aggregates may sensitively capture important individual differences at the most informative level of analysis for infant research (Sroufe & Waters, 1977).

Participants

Of an original sample of 110, 98 infants aged 10 months 5 days to 12 months, 25 days ($M = 11$ months, 23 days, 54 girls) completed the preferential looking episode (12 children were excluded due to fussiness, equipment malfunction, or caregiver interference). Because of infant fussiness, video-taping shortcomings, mothers' occasional failures to execute some tasks, etc., only 75 mother-infant pairs completed the 16-minute mother-infant interaction episode. Missing data were haphazard, not systematic; the 75 children with full 16 minute interaction samples had the same age range as the full sample of 98 (10;05 to 12;25) with a mean age of 11 months, 25 days (compared to 11;23). This subset of children also performed similarly ($M=.22$, $SD=.50$) as the larger group ($M=.25$, $SD=.49$) on our primary habituation measure (see below). In subsequent analyses, data reported are for these 75 infants (43 girls) who completed both sessions.

Most of the children (87%) were identified by their parents as Caucasian; the remainder was largely biracial. Most (84%) had annual family incomes of at least \$40,000.

Procedure

Intention understanding looking-time task procedures—Infants sat in a highchair, facing a curtained area, and mothers sat behind their child. The display was live-action and during habituation infants saw multiple trials of a person looking at one of two similar objects (stuffed kitties) with an expression of interest and joy. Habituation was terminated (and test trials begun) when the infant had three consecutive trials with looking times 50% or less than the total length of each infant's first three habituation trials, or when the infant had received 14 total trials. Thus, the fewest number of habituation trials any infant received was six and the maximum was 14.

Infant habituation to initial action displays was coded in several ways. As recommended by Bornstein and Sigman (1986), our primary measure was a *weighted habituation score*: in our case we compared looking time on the first two trials minus looking time on trials 5 and 6, divided by looking time on the first two ($M=.22$, $SD=.51$). We consider this measure primary because all infants had at least 6 habituation trials. This weighted score yields a statistically stronger measure that correlates highly with a simple difference score, in which looking time in the sixth trial is subtracted from looking time in the first, $r(72) = .73$, $p < .001$.

A second habituation measure constituted an *alternative weighted habituation score*: infant's looking time on the first two habituation trials minus their combined looking time on their last two habituation trials, divided by looking time on the first two (recall that infants often had more than 6 habituation trials). This alternative score ranged from -1.96 to $.88$ in our sample ($M=.45$, $SD=.48$). Our two habituation measures correlated with each other highly— $r(72) = .61$, $p < .001$ —but not completely.

Each infant received trials of the habituation scenario and then six test trials. During test trials, infants saw three consistent and three inconsistent test events in alternating order, counterbalanced such that half of infants saw the consistent event first, and half saw the inconsistent event first. In *consistent* test events, the actor first looked positively at one of the two kitties and then went on to hold that same object (consistent with an understanding that actors' intentional actions are directed by their perceptual-emotional regard). In *inconsistent* test events, the actor first looked positively at one of the kitties but then went on to hold the other one (Study 1 of Phillips, et al., 2002, details the procedure for the infants in the current research). Also counterbalanced across infants was the direction of the experimenter's gaze during habituation (left or right) and the color of the target kitty in habituation (the grey or the orange one).

Novelty preference during test trials (a comparison of the infant's looking to novel over familiarized stimuli) has also been used in individual-differences studies with infants, including infant IQ studies. For our analyses, we concentrated on a *simple test preference score* subtracting an infant's looking to the three inconsistent test events from their looking to the three consistent test events (as in Vaillant-Molina & Bahrick, 2012). For our 75 infants, this test preference score ranged from -24.52 to 36.53 ($M=.93$, $SD=11.42$). Bornstein and Sigman (1986) recommend a weighted novelty preference score of looking to inconsistent events divided by looking to the consistent plus the inconsistent events, but in our data this weighted test preference score correlates almost completely with simple test preference, $r(74) = .91$, $p < .001$.

Mother-infant play episode—Infants participated in a videotaped 6-minute free play session with their mother during which a variety of toys were available. Mothers and infants were free to direct their own play during this time in whichever way they chose, and the child was free to move about. This free play was followed by a teaching session during which the mother put the child in a highchair and then demonstrated how to play with 5 unfamiliar objects that functioned as manipulable toys (rainmaker, suction balls, chain, beads, and rattling balls), and then encouraged her child to play with these. Toys were

presented one at a time in a standardized sequence; after two minutes, the experimenter would knock on the playroom one-way mirror to let the mother know it was time to switch to the next toy. The teaching session thus totaled 10 minutes (and the entire mother-infant play episode totaled 16 minutes).

Videotapes of this interaction episode were coded for a variety of targeted infant and mother behaviors. Table 1 outlines these. Individual variables representing global measures of (a) quality of the mother-infant interaction, (b) infant joint attention behaviors, (c) imitative actions of both infant and mother, and (d) maternal mind-mindedness were tallied by a primary coder that varied across several individuals, depending on the focal codes.

Videotapes of the play and teaching session were also coded for (e) infant social-attentiveness, ratings derived from child temperament research. No existing standard infant temperament scale includes many items referring to the child's socially observant temperament (of the sort used by Wellman, et al., 2011 with preschoolers) so we devised 14 items based on the format used by Putnam, Rothbart and Gartstein (2008) and on items culled from that set, plus Rothbart (2001) and Wellman, et al. (2011). These items (see Table 1) capturing infant attention to social and to object-centered phenomena were rated on a scale from 1 ("not at all true of the child") to 4 ("very often true of the child"). These "temperament" ratings were based on a coder's best overall judgment of the child after multiple viewings of the entire free play plus teaching videos, an approach that matches the sort of global ratings that are typically the focus of infant temperament scales.

Finally, as outlined earlier, these videoed activities were coded for several other measures. One set was included for discriminant validity, and thus was expected not to correlate with our focal social-cognitive looking-time measures (described at the end of Table 1). Here were three items derived from temperament research that rated the infant's activity level.

Other measures were included to see whether significant relations discovered among our social cognition and social information measures, might more simply index general (rather than social-cognitive) competence. First, we tallied the total number of a child's non-verbal vocalizations (no child uttered conventional words) as uttered in the videoed play and interaction segments to provide a rough measure of language-related verbal expression. In addition, because of prior research showing that infant object-centered attention predicts later IQ (e.g., Bornstein & Sigman 1986), among the "temperament" variables we included two that seemed directed to general attentiveness or object-centered, rather than, social attentiveness as shown in Table 1.

While our data rest on a variety of single discrete ratings, these ratings were initially included as potentially reflecting larger factors such as socially observant sensitivity to others or overall mother-infant social responsiveness. Thus, aggregating discrete ratings into larger composites was integral to our analysis strategy. Several of the ratings seemed most pertinent to mother-child free play (e.g. joint attention, quality of mother-infant interaction) because there both partners were more unconstrained. For the others we analyzed two versions, one including only free play ratings and one including the ratings for both free play and teaching, see Table 2.

After analyses based on our initial conceptual grouping of items, we entered our discrete variables in a factor analysis to better examine their empirical interrelationships. In our final regression analyses we considered these derived factors (see Table 3) and their independent contributions to our focal looking-time dependent variables.

Reliabilities

Reliabilities for observation of infants' looking were calculated by comparing the timings of a primary coder recorded live during the looking-time testing session with looking times from a second coder, blind to the hypotheses and physical details of the displays, who observed videotapes of the infants. The two observers' looking times differed by 2s or less on 100% of the trials; they differed by less than 1s on 86% of all trials.

Coding and reliability calculations for our mother-infant interaction variables were conducted in three waves, each with a focus on different codes. Wave-1 reliabilities were calculated between a primary coder blind to our experimental hypotheses who coded all children and secondary coders who coded 13 of the same children (17% of the total sample of 75). Wave-1 reliabilities ranged from 77% to 100%, with the exception of the single code "infant imitates mother" during the teaching portion, where it was 65%. We retained this imitation code despite its modest reliability because of our prior interest in imitation, and because its reliability approximated 70% agreement. Where disagreements arose, these were resolved through discussion and the consensus code was used. Wave-2 reliabilities were calculated between a primary coder blind to our hypotheses and a secondary one who coded 20% of the total sample; reliabilities ranged from 90% to 95%. Wave-3 concerned only our 15 "temperament" ratings. These ratings were based on a best overall judgment of the child by a single coder who was familiar with all the videos from multiple viewings over more than a year's examination of the tapes and after multiple viewings of the entire free play plus teaching videos immediately prior to making her ratings. We reasoned this approach would more clearly capture the sort of global (often parent) ratings that are typical of infant temperament scales. For these "temperament" codes, a secondary, blind coder coded 20 (27%) children. Percentage-agreement scores ranged from 70 to 100%, with mean reliability across the eight items equaling 84.2%. Where disagreements occurred, the primary coder's rating was used.

Results

On average, as expected, infants' looking decreased over their habituation trials: 7.09s decrement from the average of the first two habituation trials to trials 5 and 6; 11.99s from the first 2 trials to the last 2. During habituation three factors (right-left placement of the two kitties, adult focus of attention on one kitty over the other, adult focus to the right or the left) were counterbalanced. In an ANOVA including these counterbalancing variables, with primary habituation score as the dependent variable, no significant effect emerged, $F(5,72)=1.09$, $p=.37$. On average, infants looked equally to the consistent and inconsistent test events. This was expected due to the age of these infants, 10- to 12-month-olds. By 12 and 14 months infants look predominantly at the inconsistent test event in this task (Phillips, et al. 2004). But at that age test preference scores are also more restricted, which could

negatively influence individual difference analyses of the type we undertake (for example, test preference scores for 14-month-olds in Phillips, et al. would have been -7.9 to 2.9 , whereas our range was -24.5 to 36.5).

Based on our *a priori* hypotheses as well as initial inspection of the set of bivariate correlations, we composed the several summary, social-interaction aggregates listed in Table 2 to relate to the looking-time measures from our habituation paradigm. Table 4 outlines our significant findings focusing on these initial summary aggregates. As noted in the table, the *primary habituation score* correlated significantly with several factors describing the interaction between mother and child, including the aggregates “quality of mother interaction” during the free play session, “joint attention”, “imitation”, and “socially observant infant temperament” (this last marginally so). These effects were positive, indicating that infants who habituated more quickly and fluently to the intentional action displays were more likely to engage in these other social-interactive experiences. “Maternal mind mindedness” did not correlate with the primary habituation score.

These effects with our primary habituation measure were representative of effects generated from using the alternative weighted habituation measure as well. Indeed, three of these four effects were significant for both habituation measures. This alternative habituation measure was also correlated with the number of maternal references to desire (see Table 4). Surprisingly, this single correlation was the only indication of a relationship between maternal mind-mindedness and infant social cognition as measured in our looking time procedure. The overall mind-mindedness composite (including mother’s uses of thought, emotion, or desire terms with her baby) correlated with no looking time measure and neither did references to thoughts or emotions separately.

In contrast to these significant correlations for habituation measures, none of our factors significantly related to test preference, and even a fine grained inspection of every single individual rating yielded only two effects, one significant and one marginal. We report those in Table 4 for sake of contrast and completeness, but these are so few they could be the products of chance alone. Because, on average infants did not look longer at inconsistent test displays in this study, we checked whether those who did look longer were systematically different on several key interaction measures. When infants who did look longer for inconsistent test trials were compared to those who did not, they did not differ. For example, they did not differ on imitation, gaze following, or coordinated attention (t s range from -1.3 to 1.4 , p s range from $.2$ to $.9$).

When the three counterbalancing variables relevant to the test trials were entered into an ANOVA with the test preference measure, one significant effect did emerge: Infants who saw the consistent test event first had a lower test preference score ($M=-3.71$), than those who saw the inconsistent event first ($M=4.87$), $F(1,72)=11.94$, $p<.01$. However, this order effect was confined to infant’s first test pair (trials 1 and 2); in their later pairs (trials 3, 4, 5, 6) there was no such difference, $t(72)=-1.31$, $p=.20$. As a supplemental analysis therefore we used a test-preference score based on just the last 4 trials for each infant, to recalculate the same correlations as calculated with the original scoring. This analysis confirmed that only a few, scattered variables partially correlated with test preference. In short, while

multiple interaction variables correlated with infants' habituation looking-time, very few correlated and only weakly with their test-trial preferences.

Finally, infant age in days was uncorrelated with our habituation measure ($r(72) = -.072, p = .55$) or our test preference measure, $r(74) = -.13, p = .29$. This last result suggests that significant relations between infant habituation measures and social interactions were not simply a result of age-related maturation or general development.

Regression analyses allow an overall accounting of the variance in infants' habituation, given our particular set of social-interaction variables. In an initial regression, simultaneously entering our aggregate social-interaction variables (mother-infant interaction quality, joint attention, imitation, and socially observant infant "temperament") as predictors of our primary habituation variable accounted for a significant proportion of variance, $R^2 = .17$; $F(4, 59) = 2.98, p < .05$. Only the "quality of mother-infant interaction" independently demonstrated a significant relation with habituation, $\beta = .37, t = 2.48, p = .016$. A similar regression model, predicting our test preference measure, was not significant: $R^2 = .03, F(4, 60) = .44, ns$.

Discriminant Analysis

Recall that we included several items capturing infants' general activity level (expected not to correlate with our focal measures). As shown at the bottom of Table 4, the aggregate "activity level" did not correlate with our primary habituation measure, nor with our test preference measure.

Nonverbal Vocalization and Object-Centered Attention

Similarly, Table 4 shows that we found no correlation between the number of each infant's non-verbal vocalizations during the mother-infant interaction and our primary habituation measure. We also examined potential object-attentiveness measures: "seemed attentive to even quiet sounds or small movements" (an average of children's scores across free play and teaching episodes), and "lays quietly examining own fingers/toes" (in free play). These were reasonably coherent in that they correlated $r(67) = .50, p < .001$, so an *object-centered attention* aggregate was computed by averaging across these two items. As shown in Table 4, this aggregate measure of object-centered attentiveness did not correlate with our primary looking-time measures.

Further Analyses

So far, our analyses have focused on the data in terms of *a priori* constructs and aggregates we hypothesized to predict infants' looking times. Equally important, however, is a more comprehensive empirical analysis of interactions and behaviors that predict looking-time measures of infant intention understanding. Here we began with the items listed in Table 1, but considered their internal organization further. In a first step, we entered all the items outlined in Table 1, exclusive of our temperament and vocalization variables, into a factor analysis using principal component analysis with Varimax rotation. This analysis yielded a 3-factor solution, explaining 57.13% of the variance for this set of items. As shown in Table 5, the items *infant and maternal affect*, *baby imitates mother* and vice versa, and *joint*

engagement loaded highly onto Factor 1, which we will refer to as “action-emotion synchrony”. The items *infant responsiveness* and *parental non-intrusiveness* loaded highly onto Factor 2, which we call, “mother-infant responsiveness.” The items *maternal sensitivity* and *infant gaze following* loaded highly onto Factor 3, which we term “mother-infant sensitivity”.

We used reliability analysis to further consider our infant “temperament” items. This allowed us to create a new internally-consistent “social attentiveness” composite. The infant social “temperament” items listed in Table 1 (except for “took turns back and forth in game-like exchanges”, because this equally reflects parents’ as well as infants’ behaviors) were entered into a reliability analysis, and yielded a Cronbach’s α of .57. Through an iterative process, we removed items that were reducing internal consistency until we arrived at a set of seven items with an internal consistency of $\alpha = .60$. While somewhat below a conventional cutoff of .70, we considered this sufficient to constitute an “infant social attentiveness” aggregate computed by averaging across these seven items (denoted in Table 1 with an *).

We entered these four derived factors and composites—action-emotion synchrony, mother-infant responsiveness, mother-infant sensitivity, and infant social attentiveness as listed in Table 3—into a regression predicting our primary habituation measure. To test the possibility that something like general object-centered attentiveness or general “maturity” would account for our findings, we entered age *and* the object-attentiveness aggregate noted earlier at step 1 into this regression predicting our primary habituation measure; this step was not significant. We then entered our 4 key social factors, and those factors accounted for an additional 17% of variance in our habituation measure, $R^2_{\text{change}} = .17$, $F_{\text{change}}(4,58) = 2.93$, $p < .05$. In this model, the infant social attentiveness aggregate ($\beta = .26$, $t = 2.01$, $p < .05$) and mother-infant responsiveness aggregate ($\beta = .25$, $t = 2.01$, $p < .05$) were independent predictors of social attention during the habituation portion of the looking-time study.

Discussion

The current study provides support for a hypothesized relation between traditional looking-time paradigms and their more naturalistic counterparts in mother-infant social interaction and infants’ social attention. Infants’ ability to quickly habituate to intentional displays correlated with several key attributes of their interactive experiences with their caregiver. In particular, mother and infant interaction quality, reciprocal imitation, mother and infant joint engagement skill, and infant social attentiveness in our semi-naturalistic observational context predicted infant attention to goal-directed action in an often-used habituation paradigm. These findings alone suggest that traditional looking-time studies used with infants, or at the least this looking-time task which has been used in multiple infant studies (e.g., Phillips, et al., 2002; Mumme, et al., 2007; Wellman, et al., 2004, 2008), have needed ecological validity—that is, they capture infant competencies relevant to everyday functioning with social partners.

Our data concern infants at the end of the first year of life, an age particularly well positioned for the investigation of infants’ socio-cognitive achievement. At the end of the

first year and beginning of the second, infants' socio-communicative competencies, both gestural and verbal, are emerging in force, and looking-time studies also reveal infant intention understandings blossoming at this time (e.g., Brandone & Wellman, 2009; Gergely, et al., 1995; Phillips, et al., 2002; Onishi & Baillargeon, 2005). Past research does not provide much evidence, however, of clear links between infant performance on these laboratory paradigms and real-world variability in the co-occurring infant-caregiver context. Our results support such a link at this key age. As such, they contribute to a growing literature tracking the developmental trajectory of infants' understanding of people over the first two years. Moreover, these findings help provide needed external validation for the voluminous socio-cognitive findings emerging from laboratory looking-time paradigms. To our knowledge only two prior studies have begun to do this (Brune & Woodward, 2007; Hofer, et al., 2008).

Our data and those of Brune and Woodward (2007) complement each other in that both report a concurrent relation between looking time and joint attention abilities. In Brune and Woodward, joint attention was assessed in a laboratory paradigm directly prompting infant joint attention or maternal report of pointing behavior (and they relate this to test preference data, rather than habituation). Our focus and findings probe a considerably broader array of mother-infant interaction measures than joint attention alone, and do so via naturalistic parent-infant teaching tasks and unstructured free play. Taken together, however, both sets of findings elaborate the contexts in which these relations emerge, and indicate important relations between emerging infant attention to others and their intention understanding. Similarly, our data add nicely to those reported by Hofer, et al. (2008), who report a relation between social-cognitive habituation times and a maternal controlling interaction style. We report data on a large number of infant-focused variables (in addition to controlling parenting style). These overlapping findings support each other, and our additional mother-infant measures extend our understanding of social-contextual factors positively related to infant interpretation of goal-directed behaviors.

A third study by Johnson, et al. (2007) reported an interesting relation between mother-infant attachment classification and infant looking time (in this case to a computerized simulation of helping/hindering social interactions). Our study assessed looking-times to live human actions (like those of Brune & Woodward and Hofer, et al.) and more broadly assessed mother-infant interaction from naturalistic teaching and free play contexts (outside the attachment context). In addition, in contrast to all of these prior studies, we provide evidence that these looking-time measures of social cognition are related specifically to mother-infant interaction—other variables, such as activity level, as well as proxies for verbal competence and object-attentiveness, did not predict infant attention to intentional action.

Our analyses of verbal competence and object-attentiveness deserve further discussion. These proxy variables were included to represent two different forms of more general infant competence. As such, they did not intercorrelate. Moreover, infant object-attentiveness in particular was included because in infant "IQ" research (see Bornstein & Sigman 1986), looking-time measures of infant attention to non-social, or perceptual-attentional stimuli (e.g., object arrays or static faces) predict later preschool IQ (e.g., Stanford-Binet scores)

and verbal competence (e.g., PPVT vocabulary scores). If our intentional-action looking-time measures were highly correlated with general object-attentiveness or predicted infant verbal (in our case preverbal) differences then they could be more appropriately interpreted as simply looking-time measures of general object-centered attention or infant IQ. The looking-time measures we consider are more discriminant than that; they are predictive of and predicted by mother-infant interaction measures but *not* preverbal fluency or object-perceptual attentiveness, as observationally coded in the rich, naturalistic context that was the target of this investigation. That said, the current study did not include a traditional measure of preschool IQ nor an alternative perceptual-object habituation task to assess object-centered looking time. It is therefore possible that our findings may still reflect some aspect of more general infant competence. A definitive examination of our hypotheses would test the same infants on contrasting perceptual-attention and social-attention looking-time tasks, as well as various mother-infant interaction variables, and then test them on social cognition as well as IQ as preschoolers. Our results provide a needed platform for designing such future studies.

One strength of the current study is the inclusion of both mother-infant interaction measures as well as infant “temperament” measures. While infants’ characteristic styles surely emerge in the context of their social world, these styles may play distinct roles in driving the search for social action-explanation. One style that seems key to the social constructs measured in the current study is careful, well-regulated attention to the details of one’s social partner. Infants who are socially-attentive, sensitive to their parent, and vocally responsive to their parent are those that more quickly habituated to looking-time displays linking perceptual-emotional regard and subsequent reaching behavior. This social attentiveness is also not simply the result of activity level in general or attentiveness in general – frequently moving about and redirecting their attention was not correlated with infants’ attention to our looking-time displays and neither was object-centered attentiveness. In these ways our infant data parallel the recent temperament findings showing that a socially observant, nonreactive temperament in preschoolers predicts their explicit theory of mind achievements concurrently (Lane, et al., in press) and longitudinally (Wellman et al., 2011).

Which caregiver-infant interaction characteristics causally shape infants’ early parsing of intentional action displays and which are more the products of increased socio-cognitive competency? The current study is not designed to directly address the direction of effects, and this remains an important set of questions for further research. Our data, however, do support the feasibility of such research—we demonstrate that significant connections exist—and provide guidance as to various factors to exploit and explore in future studies. In particular, our regression analyses offer some speculative direction. The aggregate “quality of mother-infant interaction”, the aggregate “infant social attentiveness”, and the derived factor “mother-infant responsiveness”, were all good predictors of infants’ habituation to our socio-emotional displays. The individual items comprising these aggregates (e.g., mother and infant positive affect, maternal sensitivity and non-intrusiveness, infant responsiveness, infant gaze following, infant imitation of mother, infant showed/gave mother objects) point to the importance of a sensitively modulated give-and-take in the mother-infant dyad beyond an influence of sensitive actions on the mother’s part alone. Such give-and-take may well

encourage the infant to notice the regularities in others' emotional regard toward displays in their environment, and subsequent intentional action. A mother's supportive allowance of appropriate initiative and independence during this process may encourage her infant to test these regularities while giving the infant freedom to do so. Perhaps, and likely, there are additional socio-cognitive competencies that underlie both. Along these lines, imitation between mother and infant represents a form of responsiveness that sustains ongoing collaborative learning. Future work might investigate the specific behaviors that drive this learning process, as well as more directly assess the relative impact of mother versus infant behaviors (to the extent these can be meaningfully disentangled). Our most revealing aggregates combine mother and infant behaviors and thus reflect a rather transactional approach that, though theoretically meaningful and appropriate, might be informatively broken down still further.

It is also important to emphasize that our findings primarily concern infant *habituation* to socio-cognitive displays, and that we did not find our test preference measures to be correlated with mother-infant interaction variables. This is consistent with some prior work that suggests that novelty preference may be less predictive than habituation performance in infant social-cognitive research. Thus in research using very similar looking-time procedures to ours, Wellman, et al. (2004, 2008) and Aschersleben, et al. (2008) found correlations between infant habituation of attention and preschool theory of mind, but not novelty preference. Although this was initially surprising, given that in studies of infant IQ both habituation and novelty preference correlate to later preschool IQ, Wellman, et al. (2008) argued that in infant IQ research novelty preference compares test stimuli identical with those presented in habituation to novel stimuli (e.g., Colombo, Mitchell, O'Brien, & Horowitz, 1987; Rose, Feldman, & Wallace, 1988). In contrast, in contemporary studies of infants' physical and social cognition (e.g., Spelke, et al., 1992; Wellman, et al., 2004; Woodward, 1998, and the present study) both consistent and inconsistent test events differ from habituation and thus, strictly speaking, are novel. In these paradigms, attention during habituation may an especially informative individual-differences measure. On the other hand, inconsistencies remain because novelty preference in tasks similar to ours does correlate with some later and concurrent social-cognitive measures, namely with a measure of joint attention (Brune & Woodward, 2007) and with a measure of later, preschool theory of mind (Yamaguchi, et al., 2009). Recall as well that in our study these 10- and 11-month-olds did not show systematic preference for the inconsistent test events. Perhaps test preference would also relate to relevant interaction measures in somewhat older infants with clearer test preferences. At the least, habituation measures deserve note for their demonstrated ability to capture variation in infant sensitivity to regularities of intentional behavior both in our data and in several longitudinal studies (Wellman, et al., 2004, 2008). We agree with others (e.g., Colombo & Mitchell, 2009) who advocate the use of habituation measures with infants as a valid, and valuable, measure of learning in their own right.

While we had an *a priori* rationale for focusing our analyses, the current investigation also proceeded in an exploratory fashion. Our initial approach involved scrutinizing a large number of variables and then creating four conceptually-driven aggregates. We then performed systematic post hoc analyses on the entire set of variables. Both of these

strategies yielded analyses that were data-driven in certain ways. The merit of this sort of investigation is in uncovering proven, predictive variables for still further research. Future work focused on the variables we have uncovered in a more confirmatory design would allow for greater understanding of the fine-grained interpersonal dynamics that define the sorts of mother-infant interactions contributing to and reflecting the infant's emerging social cognition.

We had hypothesized that infants of mothers who regularly reference internal states—who evidence maternal mind-mindedness—would show increased sensitivity to the social-attentional aspects of our habituation displays. Previous literature has shown linkages between mother references of this kind and heightened performance on traditional theory of mind tasks (e.g., Ruffman, et al., 2002). The absence of the hypothesized relation in the current research may have been due to the low level of mothers' use of these words in their interactions at all: 31 of the 75 mothers used none of these in free play and teaching sessions. It may be that mothers do not use these words with infants of this age with enough frequency, or specificity, in this context for a relationship to emerge. Or it may be that infants benefit from these references less *concurrently* than they do long-term. This deserves further scrutiny.

In sum, the current study contributes to our understanding of the complex socio-communicative milieu of infants' first year. Infants' characteristic ways of interacting with their world, as well as the cascade of experiences connecting them to their caregivers, certainly are reflected in their interpretation of the intentional action displays used in laboratory looking-time studies. Potentially, infants are utilizing the regularities in their interpersonal environment to build theories that guide their interpretation of others' behavior several years later. Regardless, in infancy itself these regularities are demonstrably linked to infants' attention to the intentional actions and reactions of those around them.

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Table 1**Variables Coded From Free Play and Teaching, by Category***Mother-infant Interaction*

positive affect for both mother and infant (ranging from predominant or intense negative affect (0) to predominant or intense positive affect (3))

maternal sensitivity (ranging from flat or harsh maternal behavior (0), to genuinely interested and pleased behavior (3))

maternal non-intrusiveness (ranging from controlling and overstimulating (0) to flexible availability that allows for child initiative (3))

infant responsiveness (a measure of the infant's response to the mother's attempts at engagement, ranging from ignoring mother's attempts (0) to continual attending to and engagement with mother's attempts (3))

joint engagement (counted when infant looks from an object to the mother's face and back again for at least 3 seconds)

infant gaze following (counted when mother turns her head 90 degrees and infant immediately turns own gaze in the same direction)

imitation for both mother and infant (counted when mother imitates infant's action on object, or vice versa)

Maternal Mind-mindedness

mother's use of internal state words: emotion, desire, thought (each instance of maternal use of these terms to refer to infant was counted)

Infant Social "Temperament" (all rated from 1 to 4)

infant noticed parent's facial expression (free play, teaching)

infant liked to sit and watch parent do things (free play)

infant made talking or vocal sounds when parent talked to him/her* (free play, teaching)

infant took turns back and forth in game-like exchanges (free play, teaching)

infant was wary of adult experimenters* (teaching)

infant seemed to want to watch mom with toys more than use them him/herself (free play, teaching)

infant seemed slow to warm up to the free play session (free play)

infant pointed (with fingers, whole hand, or more general arm movement) to ask to indicate interest in something* (free play, teaching)

infant showed/gave mother objects (bringing to her or extending arm to mom with held object)* (free play, teaching)

infant tried to attract mom's attention to his/her own activity (free play)

Object Centered Attentiveness (all rated from 1 to 4)

Infant was attentive to even quiet sounds or small movements (free play, teaching)

Infant lay quietly examining own fingers/toes (free play)

Infant Actions and Interactions Hypothesized Not to Relate to Intention Understanding

Infant activity level (all rated 1 to 4): infant was restless and could not sit still in free play; infant went from toy to toy very quickly in free play; when in high chair (during teaching session) infant squirmed and moved about

Infant nonverbal vocalization: total number of infant gestures and communicative vocalizations (this count did not include words as none of these infants uttered a conventional word during the session; non-communicative burps, wheezes, etc. were excluded)

Infant object attentiveness: infant seemed to attend to even quiet sounds or small movements" (free play, teaching): "lays quietly examining own fingers/toes" (free play).

* Items used in the aggregate "Infant Social Attentiveness" (described in Table 3)

Table 2Initial, Conceptually-derived Aggregates^a

Quality of mother-infant interaction = mother and infant positive affect, maternal sensitivity, maternal non-intrusiveness, and infant responsiveness

Maternal mind-mindedness = mother's use of internal state words ("think", "feel", "know")

Infant joint attention = joint engagement, infant gaze following, infant took turns back and forth in game-like exchanges

Imitation = overall mother imitation of infant, overall infant imitation of mother

Socially and observant infant temperament = infant noticed parent's facial expression, infant seemed attentive to quiet sounds or small movements, infant made talking or vocal sounds when the parent talked to him/her

^a Individual items for these aggregates are described in Table 1

Table 3Empirically-derived Aggregates^a

<u>Factor 1, Action-Emotion Synchrony</u> : infant affect, parental affect, mother imitates baby, baby imitates mother, joint engagement
<u>Factor 2, Mother-Infant Responsiveness</u> : maternal non-intrusiveness during free play, infant responsiveness during free play
<u>Factor 3, Mother-Infant Sensitivity</u> : maternal sensitivity during free play, infant gaze following during free play
<u>Aggregate 4, Infant Social Attentiveness</u> : “temperament” items “Made talking sounds when mother talked to him/her”, “Pointed to ask or indicate interest in something”, “Showed/gave mother objects”, “Was wary of adult experimenters”.

^a Individual items for these factors are described in Table 1

Table 4

Correlations Between Mother-Infant Measures and Looking-Time Measures

<u>Mother-infant measures</u>	<u>M (SD)</u>	<u>Looking time measures</u>		
		<u>primary habituation</u>	<u>alternative habituation</u>	<u>test preference</u>
Quality of mother-infant interaction during free play	5.03 (0.41) ^a	.33**	.30*	-.05
Maternal mind mindedness	2.49 (2.65)	-.09	-.21	.09
Number of maternal references to DESIRE	1.67 (2.03)	-.15	-.28*	.11
Imitation	5.65 (2.90)	.26*	.30*	-.12
Socially observant infant temperament	2.29 (0.73)	.23, p=.06	.12	.08
Infant joint attention	3.65 (1.93)	.25*	.31*	-.11
Item: made talking or vocal sounds in response to parent	2.47 (1.09)	.14	.12	.24*
Item: total number of coordinated attention episodes	1.51 (2.62)	.20	.12	.23, p=.051
Infant activity level	4.14 (1.27)	.06	0	-.08
Infant nonverbal vocalization	3.79 (3.97)	.01	-.01	.21
Infant object-centered attention	1.10 (.24)	-.09	-.02	.00

*
p<.05**
p<.01

Table 5

Rotated Component Matrix for Factor Analysis

	Loadings		
	Factor 1	Factor 2	Factor 3
Infant affect (FP)	.818	.076	-.087
Parental affect (FP)	.735	.110	.049
Mother imitates baby (FP & T)	.644	-.105	.078
Joint Engagement (FP)	.613	.021	.214
Baby imitates mother (FP & T)	.556	.047	.468
Infant responsiveness (FP)	.071	.855	.096
Parental Non-intrusiveness (FP)	.018	.675	-.012
Maternal sensitivity (FP)	.066	.245	.777
Infant Gaze following (FP)	.094	-.457	.657
Eigenvalue	2.57	1.49	1.08
% of Total Variance	28.58%	16.51%	12.05%

Note. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 4 iterations. Factor loadings above .50 are bolded.

FP = Free play session; T = Teaching session.