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"Are You Interested, Baby?" Young Infants Exhibit Stable Patterns of Attention During Interaction

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The degree to which infants' current actions are influenced by previous action is fundamental to our understanding of early social and cognitive competence. In this study, we found that infant gazing manifested notable temporal dependencies during interaction with mother even when controlling for mother behaviors. The durations of infant gazes at mother's face were positively predicted by the durations of the two previous gazes at

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mother's face. Similarly, the durations of gazes away from mother's face were positively predicted by the durations of the two previous gazes of the same type. The durations of gazes at and away from mother's face, however, were not predicted by one another. This pattern suggests that infants exhibit distinct and temporally stable levels of interest in social and nonsocial features of the environment. In this report, we discuss the implications of these results for parents, for experimental research using looking time measures, and for our understanding of infants' developing communicative abilities.

Infants' temporal patterning of their social behaviors is fundamental to our understanding of their social competence (Hsu & Fogel, 2003; Messinger, Ruvolo, Ekas, & Fogel, 2010). Are young infants influenced only by their current state and the current activities of their partners? Or do consecutive infant actions exhibit a temporal dependence consistent with longer term psychological states? Investigators have documented associations in the proportion of infant expressive actions between face-to-face interactions separated by a period of maternal impassivity (the still face; Weinberg & Tronick, 1996). There have, however, been few attempts to predict the duration of individual infant behaviors within interaction.

One area in which investigators have attempted to understand temporal dependencies within interaction involves the prediction of the duration of individual epochs of infant gazing. During face-to-face interactions in the first 6 months of life, infants actively initiate and respond to their partners. They gaze at their parents' faces, for example, to communicate a readiness to engage; they gaze away from the parent's face to regulate arousal (Beebe et al., 2008; Cohn & Tronick, 1987; Crown, Feldstein, Jasnow, Beebe, & Jaffe, 2002). Stern (1974) suggested that the total duration of a cycle of infant gazing at and away from mother's face would be essentially invariant. Consequently, he argued that the durations of gazes at and away from mother's face were likely to be inversely related. He did not, however, find evidence for such an inverse association. Kaye and Fogel (1980) found that the durations of consecutive cycles of gazing away and then gazing at mother were unrelated. In sum, previous attempts to discern patterns involving a consecutive gaze at mother and gaze away from mother have been relatively unsuccessful. Here, we adopt a different approach.

We investigated associations between the durations of successive individual gazes at mother's face, and between successive gazes away from mother's face. If successive gazes of the same type are positively associated, these temporal dependencies might suggest that young infants exhibit ongoing patterns of interest during the course of interaction. To understand

these associations in a developmental context, we examined infant–mother interaction longitudinally in the first 6 months of life. In previous analyses of these data, we found that the total proportion of interactive sessions in which infants gazed at their mothers' faces decreased with age (Fogel, Messinger, Dickson, & Hsu, 1999); likewise, Yale, Messinger, & Cobo-Lewis, (2003) found that the durations of individual infant gazes at mother's face decreased with age. Consequently, we investigated infant age as a predictor of the durations of individual gazes at mother's face and away from mother's face.

Infants and mothers influence the timing of one another's behaviors as early as 6 weeks of age (Crown et al., 2002; Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001). Prediction analyses controlled for a set of mother actions that might influence infant gaze durations. Previous analyses of the current data set indicated that the proportion of sessions in which mothers held their infants in upright positions was negatively associated with infant gazing at mother (Fogel et al., 1999). Other investigations have documented associations between mother smiling and infant gaze direction (Cohn & Tronick, 1987; Kaye & Fogel, 1980). The current analyses predicting the duration of individual gazes at mother's face and away from mother's face controlled for both mother smiling and mother positioning of her infant.

METHODS

Participants

Thirteen infants (8 males) and their mothers were observed during weekly face-to-face interactions. One mother was African American, the rest were European American. Eleven mothers had college experience, and all were part of two-parent families. A total of 208 infant–mother interactions occurred between 4 and 24 weeks of infant age. Observations began at a mean age of 5 weeks (range = 4–9) and ended at a mean age of 23.2 weeks (range = 22–24). There was a mean of 16.5 observations per dyad (median = 16, range = 9–20). Mothers missed sessions for reasons such as scheduling difficulties. Sessions were projected to be 300 sec and were terminated in nine instances when infants became too fussy to continue. The average duration of the sessions was 286 sec (range = 41–300).

Setting

Prior to the first interaction, mothers were instructed to play with their infants as they would at home (Fogel et al., 1999). Mothers held their infants

on their laps, and did not have access to toys or other objects during the interactions. Interactions were videotaped in a 12.5 ft × 12.5 ft carpeted laboratory playroom equipped with three remotely controlled pan–tilt–zoom video cameras.

Videotaping

A camera mounted at ceiling-level in the corner behind mother's left shoulder provided a view of the infant face and torso (as well as a silhouette of the mother's head). A camera mounted at shoulder level in the opposite corner of the room provided a view of the mother's face, torso, and hands. During recording, a researcher determined whether, the video-feed from one of the primary cameras should be replaced by that provided by an alternate wall-mounted camera to the side of the dyad. The two selected camera images were integrated into a composite split-screen image containing superimposed time code accurate to one thirtieth of a second (a video frame), which was recorded for coding.

Coding

Coding was conducted by manually entering the time code and behavioral code into a text file. Interrater reliability was assessed using 15% of infant gaze coding, 15% of mother smile coding, and 10% of mother positioning data. Agreement and disagreement were tabulated for each frame of video. Independent observers reliably coded the duration of gazing at and gazing away from mother's face (any element of the surroundings that was not the mother's face), agreement = 90% and Kappa = .77 (Messinger, Fogel, & Dickson, 2001). The durations of gazes at and away from mother were positively skewed and log10 transformations of gaze durations were used in all analyses. This resulted in approximately normal distributions. Mother smiling was coded reliably by observers certified in the Facial Action Coding System, agreement = 87% and Kappa = .75 (Messinger et al., 2001). Mother positioning of the infant was coded as upright (including sitting or standing on mother's lap) and other (including lying horizontally on the mother's lap or cradled in the mother's arms). Kappa for interrater reliability on postural position, .94, indicated high agreement (Fogel et al., 1999).

Modeling

Separate hierarchical linear models (Raudenbush & Bryk, 2002) were used to predict the durations of individual gazes at mother's face and

the durations of individual gazes away from mother's face. These hierarchical models—conducted using HLM 6.06 (Scientific Software International, Inc., Lincolnwood, IL) —simultaneously estimate a within-dyad model (Level 1) and a between-dyad model (Level 2). All parameters in the model were specified as random. Our focus was the prediction of individual gaze durations within dyads at Level 1. We refer to the gaze duration being predicted as the target gaze (see Figure 1).

Predictor variables

Predictors of the target gaze included the durations of previous gazes of the same type as the target gaze, age, the interaction of age and the previous gaze duration of the same type, and the immediately preceding gaze of the other type. Age was modeled as a linear effect as preliminary analyses revealed no curvilinear effects. Control variables—the presence and absence of mother smiling and infant position (upright or not) at the onset and at the offset of the target gaze—were then introduced (see Table 1).

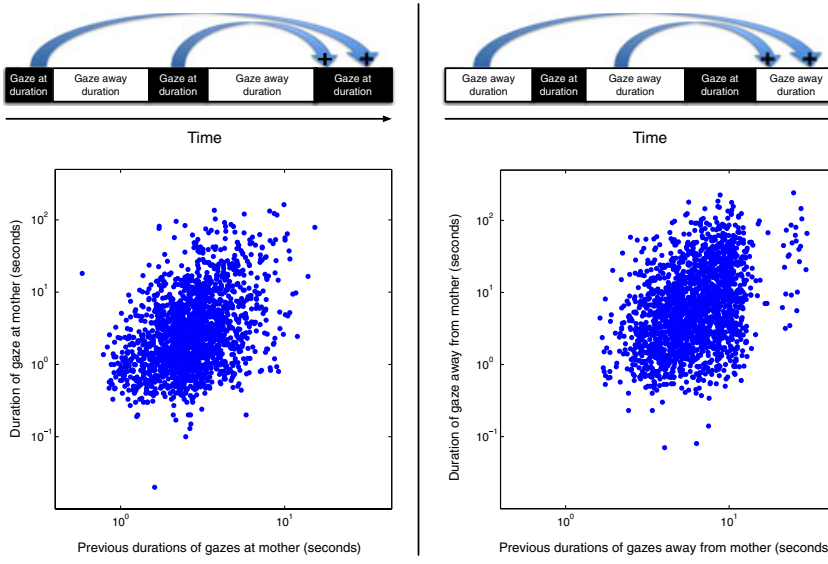

Figure 1 Values on the *x*-axes represent coefficient-weighted durations of the previous two gazes at the mother's face (left) and away from the mother's face (right). Values on the *y*-axes represent the observed target durations. The legends above the graphs illustrate these temporal associations.

TABLE 1
Coefficient Estimates for the Associations Between the Durations of Target Infant Gazes and Previous Gazes at and Away From the Mother's Face, Controlling for Age, and Mother Behaviors

Coefficients	*β*	*SE*	*T*	*p-Value*
Target: Gaze at mother duration				
β_0 (Intercept)	.429	0.025	17.315	.000
β_1 (Age)	−.015	0.004	−3.613	.004
β_2 (GM Lag 1)	.160	0.029	5.581	.000
β_3 (GM Lag 2)	.124	0.033	3.804	.003
β_4 (GA Lag 1)	−.013	0.028	−0.445	.664
β_5 (Age × GM Lag 1)	−.006	0.004	−1.444	.174
β_6 (Mother Smile at Onset)	.003	0.030	0.085	.934
β_7 (Mother Smile at Offset)	.066	0.044	1.496	.160
β_8 (Position at Onset)	−.078	0.078	−0.993	.341
β_9 (Position at Offset)	−.083	0.079	−1.043	.318
Target: Gaze away from mother duration				
β_0 (Intercept)	.812	0.049	16.495	.000
β_1 (Age)	.015	0.003	4.584	.001
β_2 (GA Lag 1)	.106	0.030	3.511	.005
β_3 (GA Lag 2)	.075	0.030	2.459	.030
β_4 (GM Lag 1)	−.039	0.030	−1.275	.227
β_5 (Age × GA Lag 1)	.002	0.006	0.372	.716
β_6 (Mother Smile at Onset)	−.024	0.036	−0.651	.527
β_7 (Mother Smile at Offset)	−.013	0.033	−0.396	.699
β_8 (Position at Onset)	.079	0.084	0.938	.367
β_9 (Position at Offset)	−.007	0.081	−0.089	.931

Notes. The durations of successive infant gazes at mother's face were modeled with random coefficients: β_0 (Intercept), β_1 (Age in weeks), β_2 (GM Lag 1, the duration of the previous gaze at mother's face), β_3 (GM Lag 2, the duration of the gaze at the mother's face previous to Lag 1), β_4 (GA Lag 1, the duration of gazing away from the mother's face immediately previous to the target gaze at mother), β_5 (Age × GM Lag 1, the interaction between infant age and the previous duration of gaze at the mother), β_6 (Mother Smiling presence at the onset of the target gaze at mother), β_7 (Mother Smiling presence at the offset of the target gaze), β_8 (Infant Positioned Upright at the onset of the target gaze), and β_9 (Infant Positioned Upright at the offset of the target gaze). A symmetrical model was specified for predicting the duration of infant gazes away from the mother's face. In this model, all "gaze-at" terms become "gaze-away" terms, and vice versa. Gazes at mother's face were predicted by previous gazes at mother's face; gazes away from mother's face were predicted by previous gazes away from mother's face. Both were predicted by age.

RESULTS

Age

As infants grew older, the durations of their gazes at the mother's face decreased and the durations of their gazes away from the mother's face

increased (see Table 1). To estimate these effects, we back transformed the mean log values of gaze durations for the first (4–7) and last (21–24) 4 weeks of observation. Between these epochs, the estimated durations of infant gazes at mother's face decreased from 5.00 to 1.80 sec. The estimated durations of infant gazes away from mother's face increased from 5.45 to 8.29 sec. Within this developmental context, we examined the effects of previous gaze durations on the target gaze.

Effects of previous gazes

The duration of an infant's gaze at the mother's face was positively associated with the duration of both the infant's previous gaze at the mother's face, and the duration of the gaze at mother's face previous to that (see Table 1 and Figure 1). Results for gazes away from mother's face paralleled those for gazes at mother's face. The duration of an infant gaze away from the mother's face was positively predicted by the duration of the previous gaze away from mother's face, and the duration of the gaze away from mother's face previous to that (see Table 1 and Figure 1).

Specificity of effects

The durations of gazes at the mother's face were not predicted by the durations of the immediately previous gaze away from the mother's face. Likewise, the durations of gazes away from the mother's face were not predicted by the durations of the immediately previous gaze at the mother's face. This indicates specificity in temporal dependencies. Each type of gaze was predicted only by the preceding gazes of the same type (see Figure 1).

Absence of interactions

Although age effects were significant, the interaction terms between previous gazes and age were not significant. This held both for gazes at and away from mother's face. The lack of an interaction effect indicates that the degree to which target gaze durations were associated with previous gaze durations of the same type did not change with infant age.

Mother behaviors

Mother behaviors were not associated with the duration of infant gazes. Specifically, the presence of mother smiling at the onset and the offset of the target gaze was not associated with the duration of gazes at mother's face or away from mother's face (see Table 1). Similarly, the mother's positioning

of the infant into an upright stance at the onset and at the offset of the target gaze also did not influence the target gaze duration.

DISCUSSION

By 12 months of age, infants combine sequences of gazes to object and persons in a manner that suggests communicative purpose (Messinger & Fogel, 1998; Mundy et al., 2007). Before 6 months of age, however, little is known about the degree to which infant actions are temporally bound to previous actions. Time-series analyses indicate a general level of temporal association between successive time samples of infant behaviors such as gazing during interaction. Among 4-month-olds, for example, a 1-sec epoch of infant gazing at (or away from) the parent was associated with the same behavior during the prior 3 sec of observation (Beebe et al., 2007). Yet, attempts to model the durations of individual infant gazes—a central signal of infant engagement—have not been successful (Kaye & Fogel, 1980; Stern, 1974.).

We investigated temporal dependencies in the duration of infant gazes at mother's face and away from mother's face—building blocks of early social engagement. From early in development, infant gaze durations exhibited temporal coherence over multiple actions (see Figure 1). Longer gazes at mother tended to follow longer gazes while shorter gazes tended to follow shorter gazes. The same pattern held, independently, for gazes away from mother's face. The duration of a gaze was influenced by the durations of the two previous gazes of the same type; this created running temporal dependencies over consecutive sequences of three actions. These temporal dependencies suggest that patterns of ongoing attention—which we refer to as interest—underlie individual epochs of gazing.

In addition to interest, other factors, such as arousal, might be a source of consistency in infant gaze patterns. Gazes at mother's face might be associated with increases in infant arousal such that longer gazes would reflect greater arousal (Cohn & Tronick, 1987; Stern, 1974). Gazes away from mother's face might be associated with reductions in arousal such that longer gazes of this type would reflect greater arousal reduction. An arousal explanation would seem to suggest, however, a positive association between successive gaze types. Periods of greater arousal while gazing at mother's face, for example, would be followed by longer periods of gazing away from mother's face to regulate arousal. With Stern (1974), however, we found that the durations of gazes at mother's face were relatively independent of gazes away from mother's face. Nevertheless, the role of arousal and affect in the temporal patterning of infant actions such as gaze direction may be a fruitful area of future research.

In the current investigation, infant gaze direction was categorized as at mother's face (representing a social focus of attention), or away from mother's face (representing a nonsocial focus). We found that the durations of adjacent gazes at and away from mother's face were not associated, suggesting the relative independence of these foci. In habituation studies, however, infant gazes away from a given stimulus are thought to index a decrease in interest to that stimulus. The current findings may, in fact, have a bearing on infant behavior in experimental protocols that use looking time as a dependent measure, such as paired preference and habituation paradigms. Although habituation involves reductions in infant gazing to a stimulus over time, we are not aware of analyses of such procedures that consider the temporal dependence of successive gazes. The existence of these dependencies could provide additional insight into predictors of infant attention during both habituation and paired preference procedures (Colombo & Mitchell, 2009; Flom & Bahrick, 2010).

Although we observed face-to-face interactions that did not involve toys or other objects, it is possible that infant gaze durations were influenced by a preference for some particular aspect of the nonsocial surround. These might include the mother's torso, the walls of the room, or the infants' own bodies (e.g., their hands). Future investigations might involve toys and distinguish between different toys and other nonsocial foci. If infants' successive gazes to a particular object or aspect of the environment were found to exhibit the temporal dependencies documented here, this would strengthen the claim that young infants exhibit stable patterns of interest.

Infant gaze durations suggested relatively independent patterns of interest in social and nonsocial features of the environment. Infant gazes at mother were predicted by previous gazes at mother, but not by the immediately preceding gaze away from mother. For parents, it may be important to know that the length of time an infant is gazing away from the parent's face appears to reflect an interest in nonsocial features of the environment, rather than a lack of interest in the parent (Beebe et al., 2007; Stern, 1974).

The lack of associations between mother behaviors and the durations of infant gazes was noteworthy. Both mother smiling and the mother's positioning of the infant's torso are associated with the direction of infant gaze when these variables are aggregated over interactive sessions (Fogel et al., 1999; Kaye & Fogel, 1980). Over the course of an interactive session, that is, holding an infant in an upright position is associated with lower proportions of infant gazing at mother's face; mother smiling tends to be associated with infant gazing. Mothers occasionally appeared to use both upright and nonupright en face positions in an apparent attempt to attract infant attention to their faces, and smiled when they had attracted the infant's attention. Yet, neither variable was associated with the duration of *individual* infant

gazes. This underscores the difference between patterns present when aggregating over the course of an interactive session, and the challenging variability associated with attempts to model infants' online social behavior (Hsu & Fogel, 2003; Messinger et al., 2010).

Although measured mother behaviors did not affect infant gaze durations, it is possible that unmeasured mother behaviors may have contributed to the observed associations between successive infant gazes. Crown et al. (2002), for example, found that mother vocalizing was positively associated with subsequent infant gazing at mother's face. Future investigations of the sequencing of infant behaviors should control not only for mother smiling and positioning of the infant but also for additional mother behaviors such as vocalizing and brow raising in an effort to rule out alternate explanations for the temporal dependence observed between the durations of successive infant gazes.

In the current report, the durations of individual infant gazes were the unit and focus of analysis. It is possible that, if mother behaviors were made the focus of analysis, they would impact the likelihood of infants switching gaze direction. Whether or not such associations exist, however, successive infant gaze durations exhibited serial dependencies, and these dependencies remained significant when controlling for mother behaviors.

Infant age served as a developmental context for the current investigation. Infants' tendency to gaze at mother's face more briefly with increasing age may reflect their increasing familiarity with the mother's face (see also Yale et al., 2003). Infants' tendency to gaze away from mother for increasingly longer periods with increasing age probably reflects heightening interest in nonsocial features of the environment (Kaye & Fogel, 1980; Messinger et al., 2010). The temporal associations between gaze durations in interaction did not change with age. Even the actions of young infants, then, are in part determined by their past experiences (Beebe et al., 2007; Colombo & Mitchell, 2009; Lewkowicz & Berent, 2009; Rovee-Collier & Cuevas, 2009).

This study reinforces a view of infants as cognitively active participants in their own engagement during naturalistic interactions (Meltzoff, Kuhl, Movellan, & Sejnowski, 2009). Infants are not simply maintaining gaze behaviors as suggested by time-series models. Instead, they modulate current behavior on the basis of previous actions. Moreover, infants' appear to be regulating their visual engagement on the basis of relatively distinct levels of interest in their partners and nonsocial elements of the environment. These levels of interest extend over multiple turns in an interactive sequence. Infants, then, are not simply acting in the here and now; instead, their behavior has a temporally embedded, historic dimension. By modulating current behavior with respect to previous behaviors

reflective of particular interests infants may be setting the stage for the development of intentional actions in which they act to attain previously formed goals.

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