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Gaze Behaviors of Preterm and Full-Term Infants in Nonsocial and Social Contexts of Increasing Dynamics: Visual Recognition, Attention Regulation, and Gaze Synchrony

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Although research has demonstrated poor visual skills in premature infants, few studies assessed infants' gaze behaviors across several domains of functioning in a single study. Thirty premature and 30 full-term 3-month-old infants were tested in three social and nonsocial tasks of increasing complexity and their gaze behavior was micro-coded. In a one-trial version of the visual recognition paradigm, where novel stimuli were paired with familiar stimuli, preterm infants showed longer first looks to novel stimuli. In the behavior response paradigm, which presented infants with 17 stimuli of increasing complexity in a predetermined "on-off" sequence, premature infants tended to look away from toys more during presentation. Finally, during mother–infant face-to-face interaction, the most dynamic interpersonal context, preterm infants and their mothers displayed short, frequent episodes of gaze synchrony, and lag-sequential analysis indicated that both mother and infant broke moments of mutual gaze within 2 sec of its initiation. The propotion of look away during the behavior response paradigm was related to lower gaze synchrony and more gaze breaks during mother–infant interactions. Results are discussed in terms of the unique and adaptive gaze patterns typical of low-risk premature infants.

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Prior to language acquisition and before infants can grasp, crawl, or stand, gaze serves as the infant's central mode of communication (Bruner, 1984; Hunnius, 2007; Messer & Vietze, 1984). Throughout life, gaze remains the most important channel of interpersonal exchange (Bavelas, Coates, & Johnson, 2002; Kurzban, 2001) and shared gaze continues to signal a willingness to interact while gaze break defines the termination of social engagement. Several neurodevelopmental and psychiatric disorders that impair the individual's social functioning are manifested in reduced eye-contact or atypical gaze behavior that may be detected already in early infancy (Watson, Hoeft, Garrett, Hall, & Reiss, 2008; Yirmiya et al., 2006), highlighting the need to study gaze behavior among infants at risk during the first stages of social engagement.

During the first 3 months of life, a rapid development of visual attention occurs (Geva, Gardner, & Karmel, 1999; Johnson, 1990) and infants move from sluggish, unfocused gaze behaviors—that attend mainly to salient stimuli and fixate inflexibly on certain objects—to faster eye movements, better scanning abilities, and more efficient disengagement of gaze (Hunnius, 2007; Hunnius, Geuze, Zweens, & Bos, 2008). This shift supports the development of face-to-face interactions between caregiver and child and the synchrony of social gaze that is required for the establishment of social engagment and the formation of attachment relationships (Feldman, 2007a). Underlying such changes are neurological maturation, environmental inputs, and the effects of social interactions on brain maturation (Hrbek, Karlberg, & Olsson, 1973; Hunnius, 2007; Kos-Pietro, Towle, Cakmur, & Spire, 1997; Madan, Jan, & Good, 2005). Nonoptimal development of the infant's gaze behavior during the first months of life, therefore, is likely to reflect structural and functional immaturity and may carry a lasting impact on the infant's neurobehavioral, social, and emotional growth.

Premature infants are considered to be at a higer developmental risk and are susceptible to motor, cognitive, attentional, language, and social–emotional difficulties (Allen, 2002; Beckwith & Rodning, 1996; Dammann et al., 1996; De-Vries & De-Groot, 2002; Hemgren & Persson, 2002; Murray, 1988; Pasman, Rotteveel, Maassen, De Graaf, & Visco, 1997). The effects of prematurity on development are often evident across childhood and up to adolescence (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Donohue, 2002; Lubetzky & Gilat, 2002; Msall & Tremont, 2002; Tideman, Nilsson, Smith, & Stjernqvist, 2002). Premature infants show difficulties in self-regulation, visual habituation (Allen & Capute, 1986), visual attention regulation (Butcher, Kalverboer, Geuze, & Stremmelaar, 2002; Geva et al., 1999; Rose, Feldman, & Jankowski, 2002a), and emotion regulation capacities (Goubet et al., 2002; Leveille, Robaey, Ge, & Lefebvre, 2002). In addition, preterm infants tend to be slower in showing preference to a novel visual stimulus and require more exposures before novelty preference is established (Rose et al., 2002a). This compromised visual processing ability is related to the premature infant's degree of medical risk. Butcher et al. (2002) showed that before 10 weeks of age (corrected for prematurity), simple gaze aversions were more frequent and quicker in preterm as compared with full-term (FT) infants, and by 16 weeks of age, premature infants were less efficient in disengaging attention from stimuli. Similarly, lower levels of social gaze and gaze synchrony—the matching of parent and infant's social gaze—were found between mothers and fathers and their premature infants during social interactions at 3 months (Feldman & Eidelman, 2007) and the overall degree of social coordination between mothers and infants is lower among preterm as compared with FT dyads (Lester, Hoffman, & Brazelton, 1985).

Studies of visual abilities in infants often focused on laboratory procedures and thus, very little information is available on infants' visual behavior in natural contexts. Moreover, very few studies examined visual abilities across several contexts and functional domains or integrated the assessment of gaze behavior during tasks that required visual attention, self-regulatory behavior, and socially focused face-to-face interactions (Colombo, 2002; Hunnius, 2007; Johnson et al., 2005). As such, the present study examined gaze behaviors across three contexts that tap different visual abilities in preterm and FT infants. We targeted a sample of low-risk premature infants according to gestational age, weight, and medical risk factors, which allowed us to isolate the effects of prematurity from other neonatal complications that often co-occur with high-risk premature birth. A microanalytical level of behavioral coding enabled the observation of subtle behavioral patterns as well as the temporal organization of interactive behaviors (Feldman, 2007a). The three contexts tested in this study varied in their dynamic complexity, that is, the degree to which infants were required not only to process a single static stimulus but also to respond to ongoing and rapidly changing situational demands. Variations across contexts also related to the level of social involvement required of the infant. In the first context, a paired-recognition task, no social interaction was required of the infant; in the second, an emotion regulation paradigm, a stranger introduced a variety of stimuli to the infant, but the social exchange was not the focus of the task and the infant was required to focus on a set of stimuli presented in a predetermined order. In comparison, the third context, a face-to-face social play between infant and mother, required the infant to respond to ongoing facial and affective cues and the behaviors of the two partners were open to mutual influences. Consistent with the micro-level approach to the assessment of behavior adaptation (Feldman, 2007a), gaze behaviors in each context were micro-coded.

The first context involved a one-trial version of the visual recognition memory (VRM) procedure, which focused on short-term simple visual processing abilities and tested the infant's preference to novelty versus familiarity (Geva et al., 1999; Rose, 1980). The VRM procedure has been widely researched in premature infants and studies have shown that the infant's maturity and medical risk are associated with visual processing on this task (Butcher et al., 2002; Gardner, Karmel, & Magnano, 1992; Geva et al., 1999). By the end of the neonatal phase and up to 3–4 months of age, research points to an interaction between endogenous and exogenous effects on visual gaze behavior in the VRM (Geva et al., 1999). With age and maturation, performance is more responsive to exogenous sources of arousal based on the development of internal executive control, and during this period, infants display shorter gaze lengths and more gaze shifts (Rose, Feldman, & Jankowski, 2001). Premature infants tend to show longer look durations, slower gaze shifts, and higher rates of off-task behaviors compared with infants born at term (Rose et al., 2001). Infants' performance on the VRM has been shown to predict cognitive development across childhood and up to early adolescence (Rose & Feldman, 1997).

The second context examined infants' regulation capacities using the behavior response paradigm (BRP; Garcia-Coll et al., 1988). In this pardigm, infants are presented with 17 unimodal (auditory, visual, tactile) and multimodal stimuli in order of increasing complexity. Each stimulus is presented for a fixed period, with a short break between stimuli, and infant gaze behavior is coded along dimensions related to arousal, fine and gross motor behavior, and regulatory capacities. This task taps the infant's visual and regulatory skills during a situation that becomes increasingly complex and intrusive but is organized in a predictable "on-off" temporal pattern. During the presentation of novel objects, infants are expected to focus their gaze on the stimulus and the degree of attention to toys is considered a marker of adaptive development (Feldman, Weller, Eidelman, & Sirota, 2002; Landry, 1995; Ruff & Lawson, 1990; Tellinghuisen, Oakes, & Tjebkes, 1999). Research has shown that premature infants tend to avert their gaze from objects more frequently (Rose, Jankowski, Feldman, & Rossem, 2005). In addition, studies have shown that preterm infants at higher risk showed greater negative arousal and poorer perforamance on the BRP as compared to low-risk premature infants (Feldman, et al., 2002; Garcia-Coll et al., 1988). Neonatal vagal regulation has also shown to predict the degree of negative emotionality during the BRP at 3 months (Doussard-Roosevelt, Porges, Scanlon, Alemi, & Scanlon, 1997) and the infant's regulatory behavior on the BRP at 3 months was found to predict self-regulatory capacities at 5 years, including self-restraint, behavior adaptation, and executive control (Feldman, 2009), pointing to the utility of this procedure to differentiate infants at higher risk for the development of self-regulation.

The third context required infants to engage in a complex interpersonal face-to-face play with their mothers. As the child's later communicative behavior is thought to originate from the early face-to-face exchange between mother and infant (Bruner, 1984), assessing mother–infant free play affords a window into the way infants integrate ongoing social–emotional signals into a meaningful communication in real time. Special attention was paid to episodes of gaze synchrony—moments in which mother and infant coordinate their social gaze; and to events of gaze break—the termination of mutual gaze following a state of gaze synchrony by mother or child. The age of 3–4 months is typically the point when infants begin to synchronize their gaze with the caregiver (Feldman, 2007b) and this experience is central for the maturation of the social brain circuitry (Johnson et al., 2005). The degree of gaze synchrony at 3 months in preterm and FT infants is predicted by cardiac vagal tone in the neonatal period (Feldman & Eidelman, 2007) and predicts, in turn, more optimal attachment behaviors at 1 year and fewer behavior problems at 2 years (Feldman & Eidelman, 2004), indicating that gaze synchrony at 3 months contributes to the development of social–emotional and communicative skills.

The current study offered the possiblity to postulate discrete and integrative hypotheses with regard to gaze behaviors of preterm infants in contexts of increasingly complex dynamics and ecological relevance. In the visual recognition task (VRM), we expected that preterm infants would exhibit longer durations of looks as compared with FT infants due to their difficulty in some aspects of visual recognition processing (Caron & Caron, 1981; Rose, Feldman, McCarton, & Wolfson, 1988), consistent with previous research at this age group (Rose et al., 2001). In the BRP, we expected that preterm infants would be less capable of focusing their gaze on the stimulus and would show more looking away behavior during object presentation as compared with FT infants (Feldman et al., 2002) due to their difficulties in regulating high levels of arousal (Goubet et al., 2002; Leveille et al., 2002). Differences between preterm and FT infants were expected to be most notable during the most dynamic mother–infant context and higher rates of gaze aversion and less focused attention on the partner would be observed in the preterm group. Moments of gaze synchrony were expected to be highly arousing for the premature infant, and we thus expected that in this group episodes of gaze synchrony would be shorter and more frequent and that both mother and infant would terminate mutual gaze more often. Finally, we explored whether gaze behaviors that are typical of preterm infants during the VRM, BRP, and mother–infant interaction would be interrelated, but as no prior research examined gaze behavior of preterms across contexts, this assessement remained as an open research question.

METHOD

Participants

Participants were 30 low-risk premature infants born before the 34th week of pregnancy and 30 FT infants and their mothers at 3 months. Age was corrected to 40 weeks gestation for the preterm group. Mothers were recruited upon discharge from the hospital and completed demographic and self-report measures. Infants were 3 months old (*M age* = 14.3 weeks, *SD* = 1.34, *range* = 12.14–17.42 weeks). Infants included in the study were all singleton babies, born to mothers from a middle-class socioeconomical background that completed at least 12 years of education and were cohabitating with the infant's father. Infants in high medical risk, with chromosomal anomalies, or with severe (III, IV) internal ventricular hemorrhaging were excluded. Demographic data regarding both experimental groups are shown in Table 1. The study was approved by the hospital's Institutional Review Board and all mothers signed an informed consent.

Procedure

A home visit was scheduled when the infant was 3 months old (corrected age for preterms) for a time of day the infant was expected to be alert and rested. The three procedures were performed in a fixed order. First, mother and infants engaged in a face-to-face interaction for 6 min. Instructions were

TABLE 1
Demographic Variables in Preterm and Full-Term Infants

Variables	*Full-term infants*	*Preterm infants*	*t or* χ^2
Birth weight (kg), *M* (*SD*)	3.294 (.361)	1.752 (.364)	16.181***
Birth week, *M* (*SD*)	39.426 (1.174)	32.245 (1.417)	21.379***
Apgar score, *M* (*SD*)	8.98 (.249)	7.91 (1.998)	2.485*
Mother's age, *M* (*SD*)	31.197 (4.445)	30.783 (4.429)	.361, n.s
Father's age, *M* (*SD*)	33.767 (5.237)	34.448 (5.847)	−.472, n.s.
Infant gender, *n* (%)			
Boys	15 (50.0)	15 (50.0)	.268, n.s.
Girls	13 (43.3)	17 (56.7)	
Number of children in family, *M* (*SD*)	2.07 (.944)	1.93 (1.617)	.390, n.s.
Infant age at home visit, *M* (*SD*)	14.429 (1.296)	14.181 (1.395)	.712, n.s.

Notes. *$p < .05$.***$p < .001$.

"play with your infant as you normally do" and interactions were videotaped for later coding from a camera that focused on the infant's face and upper body and contained the mother's face through a mirror placed in front of the mother. Within these limits, the mother chose a position that was the most comfortable for her. Toys were not provided but some mothers used the infant's own toys.

Following the mother–infant play, infants were tested in a one-trial VRM procedure (Geva et al., 1999), an abbreviated version of Rose's (1980) established paired-comparison paradigm. This paradigm was used to capitalize on the novelty aspect of the first trial in which the paradigm and presented stimuli are new (Geva et al., 1999) to avoid the effect of cross-trial learning (Jutras & Buffalo, 2010), and to avoid unnecessary taxing of the young preterm infants' resources (Tasbihsazan, Nettelbeck, & Kirby, 2003).

In the paired-comparison paradigm, the infant is initially presented with two identical targets for a familiarization phase after which the familiar target is paired repeatedly with a novel stimulus to assess familiarity and novelty preferences, examine stimuli processing patterns, and infer VRM abilities. In the one-trial VRM, the infant is seated on the mother's lap and presented with two visual stimuli that appear side by side (in accordance with Rose, 1980). This is an infant controlled phase, such that there is a 60-sec familiarization stage (stage 1) in which the infant is required to accumulate 10 sec of observing the stimulus (familiarization criterion). The 10-sec familiarization criterion was established in accordance with the infants' age (3 months corrected) and was based on Rose (1980). As the familiarization stage was infant controlled, when 10 sec were accumulated, the phase was terminated and the testing phases were introduced with no delay. In all cases studied, the criterion was established within the 60-sec period time-slot allotted.

During the testing phases, the infant is presented with a novel stimulus on either side of the screen (left/right) for 10 sec (stage 2). Side of presentation was selected in a random order. In the next stage, the novel and the familiar stimuli change positions (left/right, stage 3). The two visual stimuli, sized 12.7 cm in width and 9.3 cm in height each, were presented on a computer screen sized 31 cm × 23 cm and had a 4.5 cm space between them. The stimuli were a black and white graphic pair from the original Rose et al. (1988) study (specifically, pair 1: the sunburst and diamonds pair). These were presented using a computer software that ensured both random stimulus presentation and equal frequencies for each stimulus to be presented as novel or familiar and to appear on either the left or the right position.

In the last part of the visit, infants were tested with the BRP (Garcia-Coll et al., 1988). In this procedure, the infant is seated in an infant seat and the examiner stands beside the infant (in the infant's peripheral visual field, although no eye contact with the experimenter is encouraged) and presents the infant with 17 auditory, visual, and tactile stimuli in a predetermined order. Stimuli are organized in a sequence of increasing complexity and intrusiveness, ranging from simple unimodal (e.g., bell sound, flashlight) to aversive, multimodal stimuli (e.g., a car flashing its lights and making loud noises). Each stimulus is presented for 20 sec with a 10-sec interval between stimuli. The experimenter in this paradigm is the clear originator of actions.

Measures

Visual recognition memory

During the VRM, the direction of the infant's gaze (right, left, unfocused) was recorded to a computer by an experimenter who was obscured from view and observing the infant's gaze, while being blind to the stimuli that was presented. The computer program, Visual Studio, produced real time data regarding initial gaze durations and subsequent gaze durations toward each of the stimuli (novel, familiar) on each stage of the task. Five measures were derived from the data: (1) number of gazes to stimulus (Gaze frequency; Colombo, Harlan, & Mitchell, 1999; Hunnius et al., 2008); (2) first gaze duration in each stage (in seconds; Yang, Chen, & Zelinsky, 2009); (3) mean gaze duration throughout the procedure (in seconds; Colombo, 2002); (4) latency to familiarization criteria (i.e., length of first stage in seconds); and (5) novelty preference (i.e., percentage of mean duration of gaze at the novel stimulus in stages 2 + 3 relatively to overall gaze length at each phase; Rose et al., 1988).

Behavior response paradigm

The BRP session was micro-coded on a computerized system (The Observer; Noldus Co., The Vaggenigen, Netherlands) for the following categories of behavior, each including a set of mutually exclusive codes: Gaze, Affect, Gross Motor, Fine Motor, and Regulatory Behavior (Feldman et al., 2002). The codes on the Gaze category were used in this study and included: gaze to stimulus, look away (defined as the infant actively moving away his/her gaze from the stimulus and either looking at the examiner, looking at other objects in the environment, or gaze averting), and uncodable. Two trained undergraduate students of psychology performed the coding. Interrater reliability score were computed for 15% of the BRP sessions and reliability averaged 87.5% (kappa = .78). The frequencies of each gaze behavior was computed.

Mother–infant interactions

Mother and infant's behaviors were each micro-coded on the same computerized system in .01 sec frames for four categories of behavior: Gaze, Affect, Proximity, and Touch. Behaviors in the Gaze category, the focus of this study, included gaze to partner (social gaze), joint attention to object (mother and child look at the same object), gaze to object (only one partner looks at object), and gaze avert (directing gaze away from mother and not focusing gaze on other objects). Coding was conducted by trained graduate students and interrater reliability for 15% of the interactions averaged 87.8% (kappa = .80). Frequencies and mean durations of each gaze behavior were extracted from the coding. Two additional variables were computed:

Gaze synchrony—was computed using conditional probabilities as the number of times (frequencies) mother and infant coordinated their social gaze (infant gazes at mother given mother gazes at infant).
Gaze break—was computed using lag-sequential analysis as the number of times (frequencies) mother or infant terminated social gaze within 2 sec of the onset of gaze synchrony. Two variables were computed—"mother gaze break" (mother braking mutual gaze within 2 sec of gaze synchrony) and "infant gaze break" (infant breaking gaze within 2 sec of gaze synchrony).

RESULTS

In the first part of the results, we present differences between preterm and FT infants in gaze behavior in the three contexts. The second part examined associations between gaze behaviors in the three contexts.

Gaze behaviors of preterm and FT infants in the three contexts

Visual recognition memory

Overall, mean novelty preference scores attained by both groups were in the expected range (Preterm: M = 58.34, SD = 17.58; FT: M = 58.51 SD = 15.4) and there were no significant global differences between groups. These overall scores were attained even though the procedure used here was a one-trial paradigm with a relatively short familiarization criterion.

Analysis of variance (ANOVA) analyses were computed to examine differences between preterm and FT infants on the five measures derived from the VRM (number of gazes to stimulus, first gaze duration in each stage, mean gaze duration, latency to familiarization criteria, and novelty preference). A significant group difference was found in the duration of infant gaze in the initial novelty stage. Premature infants gazed longer at novel stimuli compared to FT infants during the initial test phase of the VRM, $F(1, 51) = 6.034$, $p < .05$. Table 2 presents mean and *SD*s for the measures derived from the VRM procedure in preterm and FT infants. As seen in Table 2, no other differences were found between preterm and FT infants in gaze behaviors during the VRM.

Pearson correlations were used to examine the associations among the different VRM measures. First gaze durations in all three VRM phases (familiarity, novelty, and reversal) were correlated (Phase 1 with Phase 2: $r = .383$, $p < .005$; Phase 1 with Phase 3: $r = .466$, $p < .001$; Phase 2 with Phase 3: $r = .383$, $p < .005$). All first gaze durations in the three VRM phases were negatively related to overall gaze frequency toward stimuli ($r = -.581$, $p < .001$; $r = -.418$, $p < .005$; $r = -.432$, $p < .005$; for Phases 1, 2, and 3, respectively) and positively associated with gaze mean duration toward stimuli ($r = .691$, $p < .001$; $r = .585$, $p < .005$; $r = .65$, $p < .001$; for Phases 1, 2, and 3, respectively). The novelty score was unrelated to any other VRM measure. It thus appears that infants who gazed longer at the stimulus when it was initially presented tended to maintain gaze for longer durations.

Behavior response paradigm

Mean durations for BRP gaze behaviors—look at stimulus and look away—are depicted in Figure 1. ANOVA analyses were computed to detect

TABLE 2
Mean Durations of Behaviors Measured During the Visual Recognition Task in Preterm and Full-Term Infants

Gaze behaviors VRM	*Full-term infants M (SD)*	*Preterm infants M (SD)*	*F(1, 51)*
First gaze length			
Phase 1	3.77 (2.54)	3.90 (3.49)	.028, n.s.
Phase 2	1.93 (1.96)	3.58 (4.02)	6.034*
Phase 3	1.98 (2.08)	3.04 (3.09)	2.397, n.s.
Familiarization time	21.07 (9.38)	19.47 (7.98)	.493, n.s.
Gaze frequency	15.46 (6.53)	14.31 (6.57)	.459, n.s.
Gaze mean duration	2.00 (.87)	2.55 (2.32)	1.471, n.s.
Novelty preference	58.51 (15.40)	58.33 (17.58)	.002, n.s.

Note. *$p < .05$.

differences in the frequency of gaze orientation between premature and FT infants during periods of "on" stimulus presentation. A main effect for prematurity was found only for look away, $F(1, 56) = 4.412, p < .05$. Premature infants tended to look away more from toys and either gaze toward the examiner or gaze avert when unfocused when the stimulus was presented to them. No difference was found between preterm and FT infants in the proportions of gaze to stimulus, $F(1, 55) = .009, p > .10$, during the BRP.

Mother–infant interactions

Two multivariate analyses of variance (MANOVAs) compared frequencies and mean durations of infant gaze behaviors (infant gaze to mother, joint attention to object, gaze to object, gaze aversion) between premature and FT dyads. Significant overall main effects were found for group in both frequencies, *Wilk's* $F(4, 55) = 6.63, p < .001$, ES = .32 and mean durations, *Wilk's* $F(4, 55) = 7.57, p < .001$, ES = .35 Univariate analysis, presented in Table 3, showed that preterm infants gazed more frequently to their mothers and initiated more gaze averts. On the other hand, these behaviors were of shorter mean durations. Overall, these findings show that

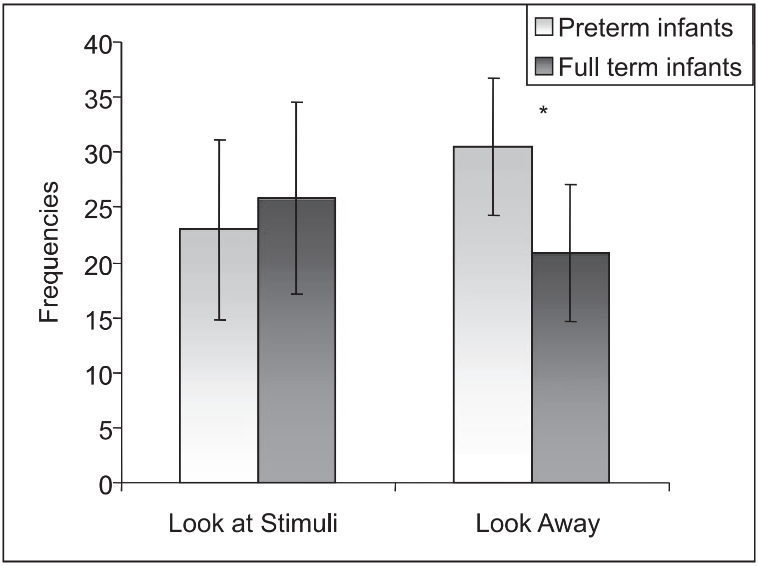

Figure 1 Mean durations of behavior measured during the behavior response paradigm (BRP) in preterm and full-term infants.

preterm infants use a pattern of short, frequent gazes to their mothers during face-to-face interactions.

Gaze synchrony and gaze breaks—Differences in the frequencies and mean durations of Gaze synchrony—defined as the co-occurrence of social gaze between mother and child—were examined using MANOVA. An overall group difference was found for gaze synchrony, *Wilk's* $F(3, 56) = 7.76$, $p < .005$, ES = .29. As can be seen in Table 3, premature infants and their mothers engaged in more frequent episodes of gaze synchrony, but each episode was of a shorter duration. This pattern resulted in an overall lower proportion of synchronous states between mothers and preterm infants. These findings further highlight the specific pattern of short, frequent gaze patterns typical of premature infants and their mothers.

Finally, differences between groups in the frequencies of Gaze breaks—defined as gaze aversions of one partner within a 2 sec period from the initiation of gaze synchrony—were computed using MANOVA. An overall group difference was found in gaze breaks, *Wilk's* $F(2, 57) = 6.31$, $p < .001$, ES = .18. Mother and infant tended to terminate their gaze within a short period of its initiation (Table 3).

Correlations between gaze behaviors in the three contexts

Pearson correlations among the following measures were tested: (i) from the VRM: first gaze duration in Phase 2; (ii) from the BRP: frequency of looking

TABLE 3
Comparisons of Frequencies of Gaze Behavior During Mother–Infant Interaction in Preterm and Full-Term Infants

Gaze behaviors infants		*Full-term infants M (SD)*	*Preterm infants M (SD)*	*F(1, 52)*
Gaze to mother	Frequency	11.40 (5.81)	18.60 (8.70)	13.515***
	Mean duration	18.23 (19.630)	7.47 (5.049)	8.192**
Joint attention	Frequency	6.07 (5.51)	5.53 (5.08)	.763, n.s.
	Mean duration	4.97 (3.66)	2.54 (1.85)	9.797**
Gaze to object	Frequency	9.20 (5.79)	15.40 (9.81)	9.035**
	Mean duration	9.37 (5.79)	8.84 (5.75)	.071, n.s.
Gaze aversion	Frequency	11.77 (6.81)	21.60 (12.19)	14.223***
	Mean duration	12.19 (7.93)	6.628 (4.11)	10.890**
Gaze synchrony	Frequency	12.06 (5.68)	19.70 (8.50)	15.931***
	Mean duration	15.16 (14.88)	6.34 (4.22)	9.672**
Gaze break				
Mother	Frequency	.20 (.40)	.96 (1.15)	11.430**
Infant	Frequency	1.06 (1.17)	3.26 (3.93)	8.370**

Notes. $p < .1$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

away from toys; and (iii) from mother–infant interactions: gaze synchrony and gaze break. The correlations are presented in Table 4.

As can be seen from the table, the first gaze length (in Phase 2 of the VRM) and the tendency to look away from toys in the BRP were marginally related ($p = .057$). Contrary to expectation, VRM gaze length was unrelated to gaze behaviors in the mother–infant context. Look away on the BRP was associated with increased infant tendency to break gaze from mother and with lower frequencies of gaze synchrony during infant–mother play. These findings suggest that more competent visual processing and better capacity to focus gaze in emotionally challenging tasks, such as the BRP, may be related higher mother–infant synchrony.

DISCUSSION

The present study examined similarities and differences in gaze behaviors between preterm and FT infants in several contexts of increasingly dynamic and socioemotional demands. Our findings identified subtle differences in gaze behaviors between premature and FT infants, which may contribute to understanding the unique developmental course of premature infants. Due to the fact that visual difficulties of premature infants are often assessed using general averaged variables from a single context (e.g., Barratt, Roach, & Leavitt, 1992) and that the evaluation of gaze behaviors in different contexts has not been conducted since the 1980s (Messer & Vietze, 1984, 1988), the data afford a close assessment of visual skills in preterm infants in relation to different contextual demands. Previous research has demonstrated that not all dimensions of visual attention differentiate preterm and FT infants (see also Rose, Feldman, Jankowski, & Caro, 2002b) and that low-risk premature infants may outperform their

TABLE 4
Correlations of Gaze Behaviors that Emerged as Differentiating Between Preterm and Full-Term Infants in the VRM and BRP and Gaze Synchrony and Gaze Break in the Mother–Infant Context

	VRM—first gaze length (A)	*BRP—look away (B)*	*Mother–infant—Gaze synchrony (C)*	*Mother–infant—Gaze break (D)*
(A)	–			
(B)	$r = .254^{\sim}$	–		
(C)	$r = -.160$	$r = -.307^{*}$	–	
(D)	$r = .093$	$r = .289^{*}$	$r = -.398^{**}$	–

Note. $^{\sim}p = .057$. $^{*}p < .05$. $^{**}p < .005$.

FT counterparts on certain visual tasks (Atkinson, 2000; Hunnius et al., 2008; Madan et al., 2005; Palmer, Dubowitz, Verghote, & Dubowitz, 1982; Ricci et al., 2008). This may be due to their earlier exposure to the visual world, but this hypothesis requires much further research (Hunnius, 2007). It is thus important to detect even minor disruptions to the visual performance of premature infants that may later impact the development of attention, regulation, and social competence (Butcher et al., 2002; Geva & Feldman, 2008).

The findings demonstrate that the interpersonal setting elicited the greatest difference between low-risk healthy preterm and FT infants. In this context, the unique characteristics of the premature infant's gaze behaviors were most notable. However, subtle and specific differences emerged between premature and FT infants both in the visual recognition task and during the emotion regulation procedure. With regards to visual recognition, infants in both groups displayed the expected percentage of novelty preference during the VRM (Fagan, 1977; Geva et al., 1999; Rose et al., 2002b) and the differences between groups was the longer duration of the first gaze in the first novelty phase of the paradigm when the novel stimuli first appeared. Premature infants exhibited a longer first gaze when initially presented with a challenge to adjust to a new stimulus. Thus, fine differences were noted between the groups in the most challenging phase of the task. This difference may be related to less efficient processing abilities in visual memory tasks, as shorter gaze durations are considered to index efficient information processing (Colombo, Mitchell, Coldren, & Freeseman, 1991; Courage & Howe, 2001; Jankowsky & Rose, 1997; Jankowsky, Rose, & Feldman, 2001). These findings support perspectives that consider the visual attention skills of premature infants to be negatively impacted by their premature birth (Butcher et al., 2002; Rose et al., 2002a). At the same time, the fact that other, more global VRM measures were not associated with prematurity, may suggest a conserved ability to regulate gaze in the face of a short and relatively simple challenge. Such compensatory behavior may not be possible under more demanding and dynamic circumstances.

Although the one-trial version of the VRM procedure has received significantly less research, it has both advantages and disadvantages in the present context. On the one hand, the classic novelty preference was replicated with the one-trial version, yet this procedure ensures lower levels of attrition and higher infant alertness during the entire task. On the other hand, infants were less able to correct their attention behavior in multiple trials. This may explain the findings that only a single variable in this procedure was significantly related to prematurity and that this measure was unrelated to gaze synchrony or gaze break in the mother–infant context. However, results from a different sample demonstrate that preterm infants' performance on the one-trial VRM at 3 months predicted more complex gaze regulatory behaviors and focused attention at 18 months (Geva, Shamir-Berman, Yaron, & Kuint, 2010), validating this procedure.

The BRP emotion regulation procedure presented the infant with a more complex and constantly changing environment and required the activation of multiple modalities that grow more dynamic and intrusive as the procedure progresses. We found that preterm infants showed more look away behavior during the presentation of increasingly complex stimuli. It is possible that premature infants are attempting to regulate the overstimulation inherent in the procedure by disengaging their gaze more frequently from the source of distress and attending to the periphery of their visual field (Gardner & Karmel, 1981). These differences between FT and preterm infants in visual attention abilities are in line with studies indicating that when the environment becomes more complex and demanding, differences between preterm and FT infants become more pronounced (Allen, 2002; Aylward, 2002).

During the most dynamic, rapidly changing, and interpersonal context, the overall visual behavior of preterm and FT infants showed a different pattern. The visual pattern of mother-preterm dyads was characterized by higher frequencies of mutual gazes, each lasting for a shorter duration. The overall proportion of gaze synchrony was lower in the preterm group and premature infants and their mothers tended to break gaze more often by averting their gaze to an object or away from the social partner. In this context, it is important to note that the shorter gaze durations and higher rates of gaze breaks typical of premature infants are not necessarily indicative of less efficient information processing. Indeed, at the age of 3–5 months reduced gaze durations and more efficient gaze disengagements may indicate better visual processing and quicker encoding of stimuli (Colombo, 2002; Colombo et al., 1991, 1999; Feldman & Mayes, 1999; Hunnius et al., 2008). Such gaze patterns may represent a dyadic regulatory effort that is partly mediated by the interacting mother who is sensitive to the special visual capacities of her premature infant.

Reduced eye contact in premature dyads was observed in lower rates of joint attention—moments when mother and child were looking at the same object. These findings provide an early illustration for the well-established differences between preterm and FT dyads in the development of joint attention skills, which are important precursors of cognitive and theory-of-mind abilities (Landry, 1995; Smith & Ulvund, 2003). Such a difficulty was observed in the lower levels of "joint" or co-attention states among premature dyads. The amount of attention infants direct to objects is influenced not only by their abilities but also by the mother's behavior (Lawson, Parrinello, & Ruff, 1992; Parrinello & Ruff, 1988). Usually, interacting with the mother increases attention toward objects, especially among infants with low attention capacities (Lawson et al., 1992). It has been shown that during the first months of life, the interacting parent assumes responsibility for coordinating their behavior with the infant's gaze (Stern, 1974). Furthermore, researchers have noted that interactions with premature infants may be less satisfying and mothers need to work harder to achieve synchronous states (Holditch-Davis, Schwartz, Black, & Scher, 2007; Schmücker et al., 2005; Singer et al., 2003). It is thus possible that premature dyads establish a unique pattern of gaze syncrony, based on the mother's intuitive evaluation of her infant's limited attentive skills (Colombo, 2002; Hunnius, 2007; Hunnius et al., 2008; Landry & Chapieski, 1988). Mothers may thus utilize the infant's capacities and adapt their behavior by providing multiple objects and directing gaze toward objects. We propose that mothers of premature infants may utilize visual attention regulation strategies, including multiple gaze breaks, preferences to new stimuli, and reliance on caregiver assistance to enhance processing of dynamic stimuli, and work to engage their infants as much as possible in the challenging dyadic exchange. Sensitive parenting takes into account the child's unique nature and abilities and adapts to the infant's developmental stage (Cox & Hartman, 2003), and the findings demonstrate such adaptation in the case of premature infants and their mothers.

The gaze patterns described here as typical of the preterm infant during early social interactions—frequent short gazes and multiple gaze breaks—may index the early precursors of the attention difficulties often detected among premature infants in later childhood (Lawson & Ruff, 2004; Ruff, Lawson, Parrinello, & Weissberg, 1990b). The present findings may suggest that such patterns of visual attention can be detected already at 3 months of age and the experimental design points to the level of environmental complexity where such difficulties are likely to appear. As individual differences in attention regulation patterns begin early and tend to persist across the first months of life (Ruff, Capozzoli, Dubiner, & Parrinello, 1990a), the present findings may serve to guide interventions that target mothers, provide information regarding their infant's capacities to attend to complex social signals, and advise on the most suited behavioral response during mother–infant play.

The findings present associations between infants' gaze behaviors in the three contexts. It appears that dyads who maintained shorter gaze synchrony periods during free play and had more gaze breaks, tended to look away more from toys presented to them during the BRP task. At the same time, prolonged first gaze to novel stimuli during the VRM was marginally associated with this increased tendency to look away in the BRP, suggesting potential carry-over of gaze behavior between contexts. The temporal organization of synchronous states between mother and infant in the first months of life is based upon physiological systems (especially oscillatory mechanisms) and has shown to predict regulatory, cognitive, emotional, and moral development later on in life up to adolescence (Feldman, 2007a, 2007b, 2007c). It is possible that the less mature physiological cycles in premature infants (Korte, Wulff, Oppe, & Siegmund, 2001) account for the differences observed in this study between FT and preterm infants. However, because we did not study gaze behavior longitudinally, it is not possible to learn from the present results which function supports the development of other visual functions. Future longitudinal designs are required in order to examine whether certain dyadic regulatory capacities serve as precursors for other gaze patterns.

The dynamic and social contexts assessed here may provide a first step to chart the typical profile of gaze behavior in premature infants. It appears that gaze in low-risk preterms is characterized by frequent attempts to self-regulate using strategies, such as gaze aversions, disengagements of gaze, frequent looks toward the periphery, and the tendency to break gaze. Higher frequencies of gaze away from the stimulus were related to more gaze breaks and lower gaze synchrony during mother–infant free play, pointing to the link between the infant's need for more intensive regulation during a challenging task and reduced ability to engage in gaze synchrony.

Future longitudinal research is required to follow gaze behavior in healthy as well as in medically compromised premature infants across a variety of domains during later infancy, early childhood, and adolescence. Since the present findings do not provide any information on causality or the possible contribution of specific gaze patterns to the formation of others. Future studies are also needed to assess the links between early visual abilities in different settings, the specific patterns of visual regulation, and the infant's later attentional, cognitive, socioemotional self-regulatory skills.

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