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Contingency, Imitation, and Affect Sharing: Foundations of Infants' Social Awareness

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Predictions about the role of contingency, imitation, and affect sharing in the development of social awareness were tested in infants during natural, imitative, and yoked conditions with their mothers at 5 and 13 weeks of age. Results showed that at both ages, infants of highly attuned mothers gazed, smiled, and vocalized positively more during the natural than during the imitative and yoked conditions, whereas they increased negative vocalizations during the yoked conditions. In contrast, infants of less attuned mothers did not differentiate between the conditions, except at 13 weeks when these infants increased their gazes during the imitative condition. Whereas contingency and imitation draw infant attention to conspecifics, affective communication appears to lay the foundation for infants' social awareness.

Keywords: dyadic interactions, affect, contingency, imitation

Early mother–infant interactions are critical for children's social, emotional, and cognitive functioning. In particular, researchers have suggested that dyadic face-to-face interactions build the foundation for communication skills (Kaye, 1982), attachment (Blehar, Lieberman, & Ainsworth, 1977), and expand an individual's state of consciousness (Tronick, 2004). Experimental manipulations, such as the still-face paradigm (Tronick, 2004), the Strange Situation (Ainsworth, 1978), and the disparaging consequences of impaired dyadic interactions (e.g., depressed mothers; Field et al., 1988), point to the importance of interpersonal "connectedness" (Tronick, 2004).

From birth, infants appear to possess a complex awareness of their conspecifics. Neonates show a preference for human stimuli (see, e.g., Reddy, Hay, Murray, & Trevarthen, 1997, for a review of this literature); they prefer facelike arrangements (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Johnson & Morton, 1991) and spend more time looking at their mothers' than at strangers' faces (Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984). Furthermore, newborns attend preferentially to human speech over other sounds and recognize the voices of their mothers over those of female strangers (DeCasper & Fifer, 1980). During the first months, infants show signs of intersubjectivity and social attunement (Stern, 1985; Trevarthen, 1979) and develop expectations about communicative interactions with people (Legerstee & Varghese, 2001). Consequently, researchers have argued that the brains of neonates may be biologically prepared for social interaction and communication (Nagy & Molnar, 2004).

There are several theoretical models that have addressed how infants become connected to the social world. Some of the most pertinent are the contingency detection theory of Gergely and Watson (1996, 1999); the active intermodal mapping theory of Meltzoff and Moore (1997); and the social interactionist theories of Fogel (1993), Legerstee (2005), Reddy et al. (1997), Stern (1985), Trevarthen (1992), Tronick (1989), and others. The purpose of the present study was to investigate these three contrasting theoretical positions and to examine infants between 1 and 3 months of age in a procedure designed to assess the theoretical predictions of these models.

Contingency Detection Theory

Gergely and Watson (1996, 1999) argued that infants are born with a contingency detection module (CDM), which helps them to infer their degree of control over the world. The authors defined contingency as consisting of three types of contingent relations: (a) temporal contingency, (b) contingent relatedness of spatial pattern (similarity of response and stimulus), and (c) contingency of relative intensity. For instance, a mirroring response is very high on these three parameters and, thus, represents a high contingent relationship (G. Gergely, personal communication, February 4, 2005).

The CDM analyzes the conditional probability of an approaching stimulus as a function of an emitted response (prospective probability) while testing the conditional probability that a stimulus event was preceded by an emitted response (retrospective probability) (Gergely & Watson, 1996; Watson, 2001). Because of an evolutionary need to distinguish the self from the environment, the CDM is genetically preset to prefer perfect contingencies, that is, behavior-based contingencies defined as relationships between

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infants' own motor responses and consequent stimulus events (Gergely & Watson, 1996). Thus, at birth, the main purpose of the CDM is the establishment of primary representations of the bodily self as a distinct object in the world (Gergely, 2001).

CDM theory predicts that after 3 months of age, infants become more attentive to stimuli that are "closer to the target criterion of best (high-but-not-perfect) contingency of the contingency detection module" (Gergely, 2001, p. 415). This preference shifts infant attention from the self to "nearly, but clearly not, like me" stimuli (Bahrick & Watson, 1985; Gergely & Watson, 1999) and orients infants toward the social environment (Gergely, 2001; Gergely & Watson, 1999; Watson, 1985).

It is with the onset of the recognition of the social environment that infants also become conscious of their emotional states. Until self-other differentiation is acquired, emotions are viewed as prewired and stimulus-dependent and therefore not accessible to conscious awareness. Emotions become accessible to the infant through affect-modulating parental interactions. If parental expressions match with children's emotions, then the caregiver's mirroring display becomes associated as a secondary representation with the infant's primary automatic affective state (Gergely & Watson, 1996, 1999), which allows infants to become aware of their own emotions. Matched emotions result in optimal development, whereas inadequate mirroring styles (e.g., lack of markedness, incongruence) may lead to pathological development (Gergely & Watson, 1996).

The finding that infants are sensitive to contingent responding has been supported by various empirical studies. For instance, Watson (1972) showed that 2-month-olds increase leg kicking when it results in a highly contingent stimulus event (i.e., rotating movement of a mobile) but not when they are presented with a similar but noncontingent event. Similarly, Bahrick and Watson (1985) revealed that by 3 months, infants prefer high but imperfect contingencies of their own legs to noncontingent images.

Research in which mother–infant interactions were examined shows that already by 6 weeks of age, infants displayed more positive affect during natural (variably contingent) interactions with their mothers, whereas showing more negative affect in response to viewing replayed interactions (noncontingent; Murray & Trevarthen, 1985). During the replayed interactions, mothers provided the same amount of social stimulation as during the natural interaction, but not in response (contingent) to what their infants did. Moreover, it has been shown that maternal interactive styles have an effect on the responses of infants younger than 3 months. Nadel and colleagues (Nadel, Carchon, Kervella, Marcelli, & Reserbat-Plantey, 1999) adopted a three-condition design (live/replay/live) by inserting a seamless shift from the initially live interaction to a replay period of a "good" maternal behavior and back again to a subsequent live interaction. The authors found that 9-week-old infants discriminated between the live and replay conditions because they reacted more negatively to the replay condition than to the two live conditions.

It is interesting to note that mothers who engaged in highly attuned interactions with their infants had infants who discriminated between the live and replay conditions. High attunement does not necessarily mean that mothers interact in a highly contingent way. According to Stern (1985), highly attuned mothers may not always rank high on "similarity of response" because they do not focus on the physical behavior of the infants to such an extent as is necessary for infant social awareness, based on CDM theory. Instead, adults tune into the infant's inner state without imitating the overt behavioral manifestations of that state.

It has been well documented that mothers who engage in less attuned interactions with their infants lack behaviors that encourage optimal levels of interactions. For example, depressed mothers spend not only less time looking, talking, and smiling at their infants but also often fail to appropriately recognize the emotional states of their infants (Field, 1984, 1992). Thus, evidence from studies in which social contingencies were examined suggests that in addition to the perception of contingencies, other factors, such as affective attunement, are important for the development of an awareness of people.

Imitation and Active Intermodal Matching (AIM) Hypothesis

Although CDM theory suggests that infants during the first 3 months do not preferentially attend to the social world, some authors propose that from birth, infants identify with people in specific human ways and that this is evident in neonatal imitation. These theorists view neonatal imitation as part of a reciprocal communication system that allows infants to understand and sympathize with others (Meltzoff & Gopnik, 1993; Meltzoff & Moore, 1997; Nagy & Molnar, 2004). To explain how matching of early acts is possible during the neonatal period, Meltzoff and Moore (1997) proposed a theoretical model of AIM in which imitation is viewed as a matching-to-target process. The reciprocal nature of the matching process is depicted by a proprioceptive feedback loop, which enables infants to evaluate their own motor performance against the seen target act. Perceived and produced behavior is processed within a supramodal framework that allows infants to notice equivalences between them. Like CDM theory, Meltzoff and Moore (1997, 1999) stressed the importance of structural similarity of parental acts, but unlike CDM theory, the authors do not emphasize the temporal contingency of imitation for an understanding of the similarity between self and other people. Through the detection of structural similarities between actions of self and other, infants come to judge others as being "like me," which, in turn, has deep psychological effects, laying the foundation for understanding other minds.

Various researchers have provided empirical support for the process of intermodal matching (e.g., Bahrick, 1988; Meltzoff & Borton, 1979). Meltzoff and Borton (1979) showed that 1-month-old infants who had been familiarized tactually with one of two shapes of dummy pacifiers showed a clear preference for the one they had sucked on, after they were tested for preferential looking with larger versions of both stimuli. Meltzoff (1990) has further provided support for part of his model by showing that as early as 6 weeks, infants are more attentive to a perfect match and thus look longer at an imitative model as opposed to a temporally contingent but spatially dissimilar model. He argued that this finding provides evidence that infants prefer when people are acting "just like me" and not just when I act. Additionally, Field, Guy, and Umbel (1985) found that 3½-month-old infants vocalized and smiled more often after being imitated than after nonimitative, spontaneous maternal behavior.

Nevertheless, various questions remain unanswered. As suggested earlier, matching or imitation would seem limiting for

sharing experiences because of its emphasis on overt behavior. Stern (1985) defined the term *affect attunement* as expressing the "quality of a shared affect state but without imitating the exact behavioral expression of the inner state" (p. 6). For instance, rather than matching the infant's negative state, parents modulate this state through expressions of sympathetic emotions, thereby providing the infant with a sense of goodness of fit that is vital for social awareness in infants (Stern, 1985; Tronick, 2004).

Affective Communication and Affect Exchange

Social interactionists propose that infants learn about themselves and other people through ongoing relationships. "Infants are participants in these relationships from the beginning of life and they share with their parents in the creation of meaning" (Fogel, 1993, p. 85). It is through these dyadic relationships that infants progress toward an increasing consensus about shared meaning. Thus, social interactionists explain developmental change as being propelled by the creativity of mutual negotiations during dyadic interactions (e.g., Fogel, 2001; Stern, 1985; Tronick, 2004; Vygotsky, 1978). These theorists argue that infants do not only characterize others as providers of certain levels of temporal contingencies or of structurally similar responses to their actions but also as beings with whom they can exchange intersubjective experiences and establish social attunement. Naturally, when connection with the social other fails, meaning is not created and enhanced (Tronick, 2004). Affective exchange is facilitated by maternal abilities to maintain infants' focus of attention, acceptance of the infant's interest, physical affection, positive affect and tone of voice, promptness and appropriateness of sensitive reactions toward infants' affective cues, and modulation of negative affect (Landry, Smith, Miller-Loncar, & Swank, 1998; Legerstee & Varghese, 2001).

The above models have important implications for an understanding of the process by which infants become aware of social agents. Consequently, their validity needs to be assessed in a study in which infant responses toward nearly perfect and imperfect contingencies are contrasted before and after 3 months of age, and the effect of the quality of affect attunement on infants' responses in these situations is being measured.

Consequently, in the present study, infants at 5 and 13 weeks of age were presented with three experimental conditions: (a) a natural interaction with their mother, (b) an imitative interaction in which mothers were instructed to imitate all infants' acts, and (c) a yoked interaction in which mothers were prompted to repeat the emotional message from the previous weeks' "conversation" with their infants. Infants' gazes, smiles, and vocalizations were measured in these interactions. In order to assess the influence of affective attunement in the dyadic interaction on infants' abilities to differentiate between the three conditions, mothers and infants were divided into highly or less attuned dyads.

Hypotheses

According to CDM theory, it is expected that at 5 and 13 weeks, infants of both highly and less attuned mothers gaze, smile, and vocalize most when presented with nearly perfect contingencies, such as in the imitative condition (i.e., when mothers respond to each infant behavior with a behavior of their own), conforming to the three characteristics of contingency (temporal, structure relational, and sensory relational), than with variable contingency (i.e., natural condition) and noncontingency (i.e., yoked condition).

According to AIM theory, it is expected that at 5 and 13 weeks, infants of highly as well as less attuned mothers gaze, smile, and vocalize most when presented with high-structural similarities such as in the imitative condition. Both groups are expected to decrease these behaviors during the yoked conditions at both ages.

According to social interactionist theories, it is expected that at 5 and 13 weeks of age, infants of highly attuned mothers gaze, smile, and vocalize most in natural conditions. Infants of less attuned mothers are not expected to respond differentially to the three conditions at 5 and 13 weeks.

Method

Participants

Overall, 82 mother–infant dyads were recruited. Five dyads did not complete the study, leaving a total of 77 mother–infant dyads (40 girls) who participated in the study. Mothers were recruited at the hospital during their maternity stay after delivery. All infants were full term, at least 36 weeks gestation (M = 39.6 weeks), and weighed a minimum of 2.555 g (M = 3.540 g) at birth. All infants were born healthy and had a 1- and 5-min APGAR score of 7 or higher. All mothers and infants were European Caucasian and came from lower- to middle-class families, based on parental education. Mothers received reimbursement for their transportation costs and a small present for participating.

Procedure

Mother–infant dyads were seen during four visits in the infancy laboratory at 4, 5, 12, and 13 weeks of age. Infants were tested when they were in a calm and alert state (Stage 4; Wolff, 1966). Infants were seated in an infant seat, approximately 30 cm from the adult. White curtains surrounded the testing area. Four digital cameras were used to film the interactions: One camera focused on the infant's face, one on the adult's face, and two others recorded the situation from the right and left side and captured both mother's and infants' face and upper body. The cameras were connected to a digital VCR with a special-effects generator to obtain a split-screen image of the situation.

Visit at 4 and 12 weeks. During the first and third visit, mothers and infants were observed in a 3-min natural interaction. Mothers were asked to interact with their infants as they normally would at home. These interactions were used to assess maternal affect attunement.

Maternal affect attunement was defined as (a) maintaining attention, (b) warm sensitivity, and (c) social responsiveness (Ainsworth, Bell, & Stayton, 1971; Landry et al., 1998; Legerstee & Varghese, 2001). *Maintaining attention* was defined as a maternal comment, request, or question related to or elaborating on the activity the infant was currently visually or physically engaged in. Maintaining attention was also coded when a maternal comment, request, or question was in direct response to the infant's attempt to attract the mother's attention to an object or activity (e.g., "Are you looking at your socks? Those are very pretty socks!"). Maintaining attention was coded on a second-by-second basis, and the proportion of the duration of maintaining attention over time (i.e., 3-min interaction) was calculated. *Warm sensitivity* was a composite assessment of the degree of sensitivity that a mother displayed to her infant's affective cues, including promptness and appropriateness of reactions, acceptance of the infant's interest, amount of physical affection, and positive affect and tone of voice. Five-point rating scales were used to make global ratings for three separate behaviors: (a) positive affect, (b) warm concern/acceptance, and (c) social responsiveness (Ainsworth et al., 1971; Landry et al., 1998).

Three ratings were made for each behavior, once every minute of each 3-min interaction, and an average was calculated for each category. *Social responsiveness* was defined as the mother's imitative responses to her infant's smile and vocalizations and modulation of any negative affect. This behavior was rated on a 5-point rating scale. A rating was made once every minute of each 3-min interaction, and an average was calculated.

These measures have been used reliably to assess affect attunement by other researchers with children of similar ages (e.g., Ainsworth et al., 1971; Landry, Miller-Loncar, Smith, & Swank, 2002; Landry et al., 1998; Legerstee & Varghese, 2001). Mothers were classified as high (HA) or low (LA) on affect attunement with respect to their scores on the subscales.

Previous research indicated that depression may affect maternal interactive style independently of her attunement (Field et al., 1988). In order to control for postpartum depression, mothers were asked to fill out the Beck Depression Inventory (BDI; Beck, 1961). This questionnaire provides information about the presence of depressed feelings and behaviors. A score of 0–9 is indicative of no or minimal depression, whereas a score of 10–16 points to the experience of a mild depression. Mothers with a score of 17–29 are assumed to be experiencing moderate depression.

To assess mothers' attitudes toward child rearing, they were administered the S-S-G (Schwangerschaft, Sexualität und Geburt [pregnancy, sexuality and birth]) questionnaire (Lukesch & Lukesch, 1976) during their first visit. This questionnaire measures mothers' opinion on five subscales, namely, Open Disapproval of Pregnancy, Fear of Injury of the Child, Unwillingness to Breast-Feed, Fear of Delivery, and Attitudes Toward Sexuality.

Visit at 5 and 13 weeks. At both their second and fourth visit, mother–infant dyads were submitted to three 1-min interactions, in counterbalanced order. In the *natural interaction*, mothers were asked to interact with their infants as they naturally would at home. During the *imitative interaction*, mothers were instructed to imitate all oral, vocal, facial/emotional, and gestural behaviors of their child. One randomly chosen minute of the 4- and 12-week interactions was used for a *yoked interaction.* In the yoked interaction, mothers listened to the interactions from their previous visit and were asked to replicate the emotional message through words and behavior. For example, if mothers heard themselves laugh or whimper, then they should try to reproduce this emotion. Mothers were further asked to repeat what they had said.

To ensure that infants in the yoked interactions were responding to their mothers as a result of temporal delay in her responsiveness rather than lack of stimulation, maternal smiles and vocalizations were assessed for a subsample of the data (40%) across situations. Smiles were operationalized as happy facial expressions, further creasing of the nasolabial fold (Ekman & Friesen, 1975) and lasting longer than 2 s. *Vocalizations* were defined as all verbalizations and utterances made.

Mothers wore headphones during all three interactions and were asked to wear the same clothes during the 4- and 5-week visits and during the 12- and 13-week visits.

To measure whether infants discriminated between the various conditions, the start and end times for infant gazes at the social partner, smiles, and vocalizations were coded (see, e.g., Delgado, Messinger, & Yale, 2002; Hsu, Fogel, & Messinger, 2001). A *gaze* was coded when the infant looked at the social partner for at least 2 s. *Smiles* were defined as elevated eyebrows and mouth corners, with the mouth either open or closed. Vocalizations were coded when a discrete sound occurred within one respiration cycle. Two separate sounds were recorded if the sound was segmented by a 1-s silence. Vegetative sounds, such as wheezes, sneezes, cough, hiccups, and effort sounds, such as grunts, were excluded. Infant vocalizations were coded as positive and negative vocalizations. *Positive vocalizations* were sounds that were emitted with either positive or neutral facial expressions. Sounds such as whimpers, fusses, cry sounds, and wails were coded as *negative vocalizations*. In order to account for slight variations in the duration of the three conditions, the proportion of the duration of gazes and smiles and the proportion of the frequency of positive/neutral and negative vocalizations over each 1-min condition were calculated and used for analyses (Legerstee, Corter, & Kienapple, 1998).

To make sure that infants were of similar mental age, infants were tested with the Bayley Scales of Infant Development (2nd ed.; Bayley, 1969) at 13 weeks of age. Infants could receive scores that classified them as either normal developing, mildly delayed, or significantly delayed.

Reliability

To assess interrater reliability, two research assistants coded infant and maternal behaviors independently. Coders were not familiar with the theoretical hypotheses and therefore could not influence the data one way or another. The first assistant coded all the data. The second assistant coded 30% of the data. Interrater reliability reached $\kappa = .82$ for gazes, $\kappa = .88$ for smiles, $\kappa = .79$ for positive vocalizations, and $\kappa = .93$ for negative vocalizations. For subscales of maternal affect attunement, interrater reliability of at least $\kappa = .83$ was obtained.

Results

Visit at 4 and 12 Weeks

Maternal affect attunement. To determine whether there was a relation between maternal maintaining attention, warm sensitivity, and social responsiveness, a correlational analysis was conducted. Results showed significant correlations between Maintaining Attention, Warm Sensitivity, and Social Responsiveness at both 4 and 12 weeks of age (see Table 1). These data indicated that mothers who had high scores on Maintaining Attention also had high scores on Warm Sensitivity and Social Responsiveness. Mothers were judged as high or low on affect attunement, according to their mean standardized scores on affect attunement at both 4 and 12 weeks.

It is often assumed that mothers, in particular during the early months, may change their affective interactive skills. In order to assess for continuity of affect attunement between 4 and 12 weeks,

Table 1
Intercorrelations Between Subscales of Affect Attunement

	4 weeks			12 weeks		
Subscale	1	2	3	1	2	3
1. Maintaining Attention	—			—		
2. Warm Sensitivity	.494**	—		.413**	—	
3. Social Responsiveness	.530**	.780**	—	.433**	.800**	—

** $p < .001$.

a correlation was calculated on the mean standardized scores, $r(77) = .498$, $p < .001$.

The means of maternal affect attunement scores were rank ordered. A natural split was observed such that 47 (61%) mothers fell into the highly attuned group, whereas 30 (39%) mothers fell into the less attuned group. This distribution of HA and LA mothers is in agreement with previous research in which affect attunement was investigated (e.g., Landry et al., 1998; Legerstee & Varghese, 2001) and also with the works of Ainsworth and colleagues on maternal sensitivity and attachment (Ainsworth, 1978; Ainsworth et al., 1971; Bell, 1970).

Control measures. Results showed that all infants were normally developing, as measured by the Bayley Scales of Infant Development, and none of the mothers were depressed, as measured by the BDI. Results of the S-S-G revealed that LA mothers had significantly different attitudes toward pregnancy and child rearing than did HA mothers. LA mothers had higher scores than HA mothers on three out of five subscales. More specifically, LA mothers showed significantly elevated scores on the subscale Open Disapproval of Pregnancy, $F(1, 74) = 5.45$, $p = .022$, $\eta^2 = .07$, indicating that these mothers had a more negative attitude toward pregnancy and their developing children. LA mothers were also more overcautious and anxious toward their children than were HA mothers, as revealed by their significantly different scores on the subscale Fear of Injury of the Child, $F(1, 75) = 6.56$, $p = .012$, $\eta^2 = .08$. LA mothers also reported more disapproving attitudes toward sexuality than did HA mothers, $F(1, 75) = 4.48$, $p = .038$, $\eta^2 = .06$.

Visit at 5 and 13 Weeks

Validation of yoked condition. Repeated measures analyses of variance (ANOVAs) were conducted for maternal smiles and vocalizations in the natural and yoked conditions. Results revealed no significant difference in maternal stimulation at both ages across the two conditions.

Gazes. A mixed-model ANOVA was calculated on gaze, with age (5 weeks, 13 weeks) and condition (natural, imitative, yoked) as the within-subject factors and maternal rank (HA, LA) and order of presentation as the between-subjects factors. No significant effect of order of presentation was found, thus this variable was eliminated from all further analyses. There was a significant Condition × Maternal Rank interaction, $F(2, 150) = 13.78$, $p < .001$, $\eta^2 = .16$, as well as a significant Age × Condition interaction, $F(2, 150) = 10.03$, $p < .001$, $\eta^2 = .12$.

Further analyses (see Table 2) revealed that at 5 weeks, HA infants gazed longer at their mothers during the natural than during the imitative condition, $F(1, 46) = 18.46$, $p < .001$, $\eta^2 = .29$, and also during the yoked condition, $F(1, 46) = 21.23$, $p < .001$, $\eta^2 = .32$. However, there was no significant difference in gazes during

Table 2
Mean Proportional Duration of Gazes, Smiles, and Positive and Negative Vocalizations in the Three Experimental Conditions for HA and LA Infants

	HA			LA		
Infant behavior	Natural	Imitation	Yoked	Natural	Imitation	Yoked
			5 weeks			
Gazes						
M	88.97	71.63	72.82	61.54	61.80	59.17
SD	9.87	25.80	24.82	28.65	27.52	32.55
Smiles						
M	7.54	1.83	2.89	2.54	2.31	0.89
SD	9.12	5.43	4.87	3.41	4.55	1.58
Positive vocalizations						
M	2.07	0.65	0.53	1.67	1.50	1.55
SD	2.44	0.84	0.52	1.40	1.69	2.80
Negative vocalizations						
M	0.22	0.29	1.94	0.25	0.56	0.42
SD	0.49	0.95	4.52	0.67	1.61	0.54
			13 weeks			
Gazes						
M	86.45	81.77	63.91	64.90	80.11	60.04
SD	13.81	12.59	19.74	22.60	20.27	12.72
Smiles						
M	16.24	7.05	9.10	4.95	2.79	3.53
SD	16.00	9.37	11.22	6.91	4.58	6.70
Positive vocalizations						
M	3.81	1.98	1.56	1.78	1.05	2.16
SD	4.40	2.75	1.23	1.79	1.39	3.47
Negative vocalizations						
M	0.39	0.25	1.60	0.43	0.78	0.48
SD	0.68	0.50	2.84	0.66	1.48	0.68

Note. HA = high on affect attunement; LA = low on affect attunement.

the imitative and yoked condition. Similarly, at 13 weeks of age, these infants gazed longer at their mothers during the natural than during the imitative condition, $F(1, 46) = 4.62$, $p = .037$, $\eta^2 = .09$, as well as during the yoked condition, $F(1, 46) = 70.90$, $p < .001$, $\eta^2 = .61$. Furthermore, HA infants gazed longer during the imitative than during the yoked condition, $F(1, 46) = 30.62$, $p < .001$, $\eta^2 = .40$.

Results for the LA infants showed that at 5 weeks, they did not gaze significantly more at their mothers in any of the three conditions. At 13 weeks, they gazed significantly longer at their mothers during the imitative than during the natural condition, $F(1, 29) = 11.17$, $p = .002$, $\eta^2 = .28$. Similarly, LA infants gazed longer during the imitative than during the yoked condition, $F(1, 29) = 21.21$, $p < .001$, $\eta^2 = .42$. There was no difference in gazes during the natural and yoked condition.

All infants significantly increased gazes at their mothers during the imitative conditions from 5 ($M = 66.716$, $SD = 27.15$) to 13 ($M = 80.936$, $SD = 16.41$) weeks of age, $F(1, 75) = 19.29$, $p < .001$, $\eta^2 = .21$, but not during the natural and yoked conditions.

Smiles. A mixed-model ANOVA was computed on smiles, with age (5 weeks, 13 weeks) and condition (natural, imitative, yoked) as the within-subject factors and maternal rank (HA, LA) and order of presentation as the between-subjects factors. No significant effect of order of presentation was found, thus this variable was eliminated from all further analyses. There was a significant Condition × Maternal Rank interaction, $F(2, 150) = 8.91$, $p < .001$, $\eta^2 = .11$, as well as a significant Age × Maternal Rank interaction, $F(1, 75) = 4.55$, $p = .036$, $\eta^2 = .06$.

Further analyses (see Table 2) indicated that at 5 weeks, HA infants smiled more often during natural than during imitative conditions, $F(1, 46) = 17.48$, $p < .001$, $\eta^2 = .28$, and more often during natural than during yoked conditions, $F(1, 46) = 13.80$, $p = .001$, $\eta^2 = .23$. However, there was no difference between imitative and yoked conditions. At 13 weeks, HA infants smiled significantly more during natural than during imitative conditions, $F(1, 46) = 15.43$, $p < .001$, $\eta^2 = .25$, and least during the yoked condition, $F(1, 46) = 14.74$, $p < .001$, $\eta^2 = .24$. There was no difference in smiles during the imitative and yoked conditions. LA infants did not smile differently at their mothers in the three conditions at both 5 and 13 weeks.

Results revealed a significant difference between smiles of HA infants ($M = 4.085$, $SD = 4.97$) and LA infants ($M = 1.914$, $SD = 6.21$) at 5 weeks of age, $F(1, 75) = 5.74$, $p = .019$, $\eta^2 = .07$, as well as at 13 weeks of age (HA infants: $M = 10.794$, $SD = 10.62$; LA infants: $M = 3.757$, $SD = 13.29$), $F(1, 75) = 13.17$, $p = .001$, $\eta^2 = .15$. Both HA and LA infants increased their smiles from 5 to 13 weeks: HA infants, $F(1, 46) = 15.07$, $p < .001$, $\eta^2 = .25$; LA infants: $F(1, 29) = 4.25$, $p = .048$, $\eta^2 = .13$.

Positive vocalizations. A mixed-model ANOVA was performed on positive vocalizations, with age (5 weeks, 13 weeks) and condition (natural, imitative, yoked) as the within-subject factors and maternal rank (HA, LA) and order of presentation as the between-subjects factors. No significant effect of order of presentation was found, thus this variable was eliminated from all further analyses. There was a significant Condition × Maternal Rank interaction, $F(2, 150) = 8.88$, $p < .001$, $\eta^2 = .11$, as well as a significant Age × Maternal Rank interaction, $F(1, 75) = 6.21$, $p = .015$, $\eta^2 = .07$.

Further analyses (see Table 2) revealed that at 5 weeks of age, HA infants produced more positive vocalizations during the natural than during the imitative condition, $F(1, 46) = 16.15$, $p < .001$, $\eta^2 = .26$, and also more often during the natural than during the yoked condition, $F(1, 46) = 19.85$, $p < .001$, $\eta^2 = .30$. No difference was found between the imitative and yoked conditions. At 13 weeks of age, HA infants produced more positive vocalizations during the natural than during the imitative condition, $F(1, 46) = 7.06$, $p = .011$, $\eta^2 = .13$, as well as during the yoked condition, $F(1, 46) = 13.52$, $p = .001$, $\eta^2 = .23$. However, there was no difference between the imitative and yoked conditions. LA infants did not vocalize differently in the three conditions at 5 and 13 weeks of age.

Results showed that HA infants increased their positive vocalizations from 5 ($M = 1.083$, $SD = 1.54$) to 13 weeks of age ($M = 2.452$, $SD = 2.42$), $F(1, 46) = 18.79$, $p < .001$, $\eta^2 = .29$. No difference was found between HA and LA infants' overall production of positive vocalizations at 5 and 13 weeks of age.

Negative vocalizations. A mixed-model ANOVA was performed on negative vocalizations, with age (5 weeks, 13 weeks) and condition (natural, imitative, yoked) as the within-subject factors and maternal rank (HA, LA) and order of presentation as the between-subjects factors. No significant effect of order was found, thus this variable was eliminated from all further analyses. There was a significant Condition × Maternal Rank interaction, $F(2, 150) = 11.43$, $p < .001$, $\eta^2 = .13$.

Further analyses (see Table 2) showed that at 5 weeks, HA infants produced significantly more negative vocalizations during the yoked than during the natural condition, $F(1, 46) = 6.85$, $p = .012$, $\eta^2 = .13$, and also more during the yoked than during the imitative condition, $F(1, 46) = 7.67$, $p = .008$, $\eta^2 = .14$. HA infants did not differentiate with their negative vocalizations between the natural and imitative conditions. At 13 weeks of age, HA infants produced significantly more negative vocalizations during the yoked than during the natural condition, $F(1, 46) = 9.94$, $p = .003$, $\eta^2 = .18$, as well as during the imitative condition, $F(1, 46) = 11.18$, $p = .002$, $\eta^2 = .20$. There was no significant difference in negative vocalizations during the natural and imitative conditions. LA infants did not differentiate with their negative vocalizations among the three conditions at both 5 and 13 weeks of age.

To summarize, although none of the mothers were depressed, they could be divided into two groups in terms of their interactive styles. HA mothers maintained the attention of their infants and ranked high on warm sensitivity and social responsiveness. LA mothers scored low on these interactive skills. At both 5 and 13 weeks of age, infants of the HA mothers gazed, smiled, and produced more positive vocalizations during the natural than during the imitative and yoked conditions, whereas they increased their negative vocalizations during the yoked conditions. Overall, LA infants did not produce different smiles or positive and negative vocalizations during the three conditions at both ages, although they increased their gazes significantly during the imitative interaction at 13 weeks.

Discussion

The aim of the present study was to examine the hypotheses of three influential theories about the development of infants' aware-

ness of the social world. Consequently, infants were observed in an experimental paradigm that assessed the predictions of these theories. To recap briefly, according to CDM theory, infants before 3 months of age prefer nearly perfect contingencies over intermittent contingencies. After 3 months, infants start to prefer high but intermittent contingencies. Because people provide infants with intermittent contingent responding, it is at that time that infants begin to orient to people. This sensitivity to people also results in infant awareness of their own and others' emotions, but only if mothers sensitively mirror their infants' emotions. AIM theory, however, proposes that infants identify with people by engaging in imitative interactions with them. Thus, in contrast to CDM theory, which stresses temporal, space relational, as well as structural relational contingencies as an important mechanism for infants to experience people as "nearly, but clearly not like me," AIM theory emphasizes only structural similarities between actions of self and others. Finally, whereas social interactionist theory acknowledges the importance of contingency and imitation as mechanisms that may make infants attentive to people, they propose that attunement through affective communication lays the foundation for infants' social awareness.

To test these theories, 5- and 13-week-old infants and their highly and less attuned mothers were observed in three conditions, namely, natural, imitative, and yoked. It was found that at both 5 and 13 weeks, HA infants gazed, smiled, and produced more positive vocalizations during the natural than during the imitative and yoked conditions but increased their negative vocalizations during the yoked conditions. LA infants did not respond differentially in the three conditions at both ages, except that they gazed longer at their imitative mother at 13 weeks of age.

CDM theory predicts that before 3 months of age, infants prefer nearly perfect contingencies that are high on temporal, space relational, and sensory relational parameters, factors mothers should provide in the imitative condition. However, none of the infants in the HA or LA group preferred the imitative condition to the others. Thus, at 5 weeks, our findings do not support the predictions put forth by CDM theory.

The CDM model further predicts that after 3 months, infants, regardless of maternal affect attunement, prefer stimuli that are closest to the target criterion (i.e., high but not perfect contingency) and that contain the three parameters described above. Thus, similarly to the earlier age, infants should prefer the imitative condition. Our findings do not support this prediction. The highest frequencies of gazes, smiles, and positive vocalizations of the HA infants were observed during the natural interaction with their mother, whereas LA infants gazed most during the imitative interaction. The absence of more social types of behaviors (e.g., smiles and positive vocalizations) during the imitative condition of LA infants suggests different bases for these responses; looking may be a result of novelty, whereas smiles and vocalizations have a potential social significance (Legerstee, Anderson, & Schaffer, 1998). It appears that LA infants increased their gazes as a response to perceptual discrepancies (high level of responsiveness in mothers who usually provide low levels of responsiveness) rather than preference for a specific level of contingency.

It could be argued that the imitative conditions did not provide infants with a very high contingency because it is presumed that mothers react in a delayed fashion to the infants' responses. However, it has been argued that infants in Watson's (1972) study were exposed to very high contingencies (G. Gergely, personal communication, February 4, 2005). In that study, infants' heads rested on a pressure-sensing pillow, which made the mobile turn 1 s after infants pressed their head on the pillow. Consequently, this mechanism did not allow the infants to perceive the mobile response as quickly as if infants had hit the mobile themselves ("lagged contingency"; G. Gergely, personal communication, February 4, 2005), nor did the response stimulus provide structurally similar contingencies to the infants. In contrast, in the imitative condition of the present study, when infants smiled during the imitative condition, mothers smiled back immediately, and when infants vocalized, so did their mothers. This maternal behavior was ensured by the instructions given prior to the onset of the condition. Moreover, other researchers have reported that caretakers, when facing young babies, naturally respond immediately and contingently to their infants' behaviors, which they argue is the result of "intuitive" parenting (e.g., Papousek & Papousek, 1984). Consequently, the imitative condition in the present study provides infants with a higher level of contingency than the mobile in Watson's (1972) paradigm.

The results at both 5 and 13 weeks appear to be in opposition to the AIM hypothesis, which predicts that at these ages, both HA and LA infants prefer imitative behaviors of their mothers to natural and yoked conditions. HA infants gazed, smiled, and vocalized positively more during natural conditions with their mothers than during imitative conditions. Although LA infants did not respond differently to the three conditions, they increased gazing at their mothers during the imitative condition at 13 weeks. As indicated above, this suggests that these infants increased gazes because maternal imitative behavior violated the way infants expected her to behave.

It could be argued that a natural interaction by an expressive mother would give infants plenty of target smiles and vocalizations to imitate. Therefore the infant's own vocalizations and smiles may increase as a result of the imitative mechanism (A. N. Meltzoff, personal communication, March 11, 2005). However, AIM theory states that infants attend preferentially to experiences that are "me relevant," which are most prominent in structural similarity between self and others. As indicated earlier, HA mothers may actually provide infants with less structurally similar types of behavior during the natural interaction than during the imitative interaction because during the natural interaction, she includes structural similarities along with elaborations on or attunements to infants' actions. Because AIM predicts that more rather than less structural similarities attract the infant's attention, infants should prefer the imitative condition and should produce more smiles and vocalizations during imitation with HA mothers than during the natural interaction with her.

Social interactionist theories predict that HA infants should be more responsive in natural interactions with their mothers at both ages because mothers tune in to their infants' attention and provide high levels of warm sensitivity and responsiveness. The results confirm these hypotheses. HA infants gazed, smiled, and vocalized positively more during the natural than during the imitative and yoked conditions. Furthermore, HA infants decreased their smiles and positive vocalizations but increased negative vocalizations during the yoked conditions. Some would argue that infants' negative responsiveness during the yoked condition is related to a lack of contingencies rather than to a lack of affective responses of

their mothers. However, the fact that only HA infants produced negative vocalizations during these conditions suggests that lack of affect attunement plays a role in infants' responsiveness. These findings support those of Legerstee and Varghese (2001). In that study, 2- to 3-month-old infants of HA and LA mothers engaged in a live interaction with their mothers over TV monitors and also viewed a replay of their mothers' interaction from the preceding week (yoked condition). The order of the conditions was counterbalanced. Infants in both groups discriminated between the two conditions because they reduced the amount of time they gazed at their mother from natural to replay. However, the finding that only infants of HA mothers reduced their positive affect suggests that whereas both groups reacted to a change in contingencies, infants of HA mothers reacted to a lack of affect sharing by reducing their own affective behaviors. These findings confirm that infants of affectively attuned mothers perceive the yoked interaction as a violation of affective sharing present in dyadic communication rather than as a function of a general lack of activity or contingency.

One could make a case that because of the high rate of maternal behaviors during the first 3 months of life, the yoked conditions may include a high amount of contingent rather than random responses of the mothers. If this were true, then there should be no differential responsiveness as a function of condition or group. However, our findings show that HA infants responded differently to the three conditions, whereas LA infants did not. Thus, the finding that LA infants did not differentiate between the natural and yoked conditions supports the suggestion by Field (1992) that LA mothers produce low affect attunement and responsiveness, and, consequently, their natural interactions are similar to their yoked interactions.

To summarize, the results of the present study show that infants who experience highly attuned interactions with their mothers gazed, smiled, and vocalized positively more in natural conditions as opposed to imitative and yoked conditions. In contrast, infants who experience less attuned interactions with their mothers did not differentiate between maternal behaviors in the natural, imitative, and yoked conditions. Thus, maternal affect attunement, as defined in this research, imposes a significant difference on infants' social competencies. The results support the theoretical and empirical writings of those who have made a case for the importance of affect sharing as a mechanism that connects infants with the social world (e.g., Fogel, 1993; Izard, 1978; Legerstee, 2005; Reddy et al., 1997; Stern, 1985; Trevarthen, 1992; Tronick, 1989). As so profoundly argued by Stern (1985), *affect attunement*, the ability to know what the other person is experiencing subjectively, underlies not only empathic understanding but also is the basis for early communication and, most importantly, provides a way for mutual appreciation of the other's mental state.

Emotion states signal information about people's mental life and may be indicative of or directive for infants' own behavior. Consequently, social partners who provide more information about their own internal states are more likely to be reciprocated. For example, studies in which the effect of maternal responsiveness on infants' development was investigated (Bornstein & Tamis-LeMonda, 1989; Brazelton, Koslowski, & Main, 1974; Landry et al., 1998; Legerstee, Varghese, & van Beek, 2002; Stern, 1985) have shown that mothers who are more sensitively responsive to infants' signals influence infants' social and cognitive competencies.

As Trevarthen (1992) suggested, children's feelings have particular characteristics that facilitate participation with a social partner's feelings in specific ways. In this light, it is not surprising that emotions shared between communicative partners generate sympathy and comfort, whereas the lack of emotional sharing and coregulation can have profoundly devastating effects on the child's well-being (see, e.g., Field, 1984; Field et al., 1988; Fogel, 1993; Kogan & Carter, 1996; Rogers & Pennington, 1991). This "emotional confluence" (Trevarthen, 1992) may represent the key ingredients for recognizing the other as "like me" and sensitize infants to others' emotional and behavioral acts that are contingent to their own.

To conclude, the results of the present study provide evidence for the importance of affect sharing during early mother–infant interactions in addition to contingent responding and imitation for the development of social understanding in infants. During affective interactions, infants recognize the social partner as being "with me" rather than "just like me" or "nearly, but clearly not like me." Merely matching or contingent responding to the infant's behavior and expressions seems not to serve communicative purposes. Affective interactions are comparable to musical duets in which,

> the two performers seek harmony and counterpoint on one beat to create together a melody that becomes a coherent and satisfying narrative of feelings in a time structure that they share completely. In a good performance by two or more musicians each partakes of, or identifies with, the expression of the whole piece, the ensemble. (Trevarthen, 1992, as cited in Bornstein & Tamis-LeMonda, 2001, p. 275)

More research and detailed theoretical models are needed to explain the importance of affect sharing and its role in early intersubjectivity.

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