IMAGINATION, COGNITION AND PERSONALITY, Vol. 32(4) 339-366, 2012-2013

AFFECT ATTUNEMENT DURING MOTHER-INFANT INTERACTION: HOW SPECIFIC INTENSITIES PREDICT THE STABILITY OF INFANTS' COORDINATED JOINT ATTENTION SKILLS*

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ABSTRACT

Associations between mother-infant affect attunement (AA) at 6 and 9 months and infant coordinated joint attention (CJA) at 12 months were examined. Fifteen dyads were videotaped at 6, 9, and 12 months during object-mediated play interactions. Videotapes were coded for intensity of matched AA at 6 and 9 months. Low-intensity affect matches at 6 and 9 months were positively associated with CJA; whereas moderate-intensity affect matches had a negative association. Results suggest shared, pleasurable, low-intensity emotional states support social-cognitive development; whereas moderate-intensity AA may be a hindrance. Between 6 and 9 months, AA may shift from understanding others' emotions to understanding others' attentions; and mutual regulation of low-intensity emotional states may facilitate infant processing capabilities.

*This article is based on Lisa Greenwald's doctoral dissertation presented to the faculty of the University of Texas at Dallas (Greenwald, 2007). This research was partially supported by a grant from the Timberlawn Foundation, UTD School of Behavioral and Brain Sciences faculty initiative award and Callier Center Excellence in Education Award to the first author. Portions of this study were presented at the 2008 International Conference for Infant Studies and the 2008 International Congress for the Study of Child Language.

© 2013, Baywood Publishing Co., Inc.
doi: http://dx.doi.org/10.2190/IC.32.4.c
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Social pragmatic theory often considers coordinated joint attention (CJA) foundational for language development (Carpenter, Nagell, & Tomasello, 1998; Tomasello & Todd, 1983). CJA occurs when infants coordinate their attention between a social partner and an object or event in the immediate environment. This marks the emergence of the intentional stance, the understanding that other people have intentions and attentions towards outside entities such as objects and events. CJA also marks the emergence of secondary intersubjectivity, the experience that objects and events are shared with one another (Rollins & Snow, 1998; Tomasello, 1999; Tomasello & Carpenter, 2007). Infants begin using CJA at about 9 to 10 months of age, but are not observed to have robust amounts until 12 to 18 months of age (Bakeman & Adamson, 1984; Carpenter et al., 1998; Rollins, 2003). It is only at these later ages when infants actively recruit their newly learned skill of CJA to promote language learning (Baldwin & Moses, 1996; Carpenter et al., 1998).

Interestingly, CJA is also a core deficit in children with Autism Spectrum Disorders (ASD) (Loveland & Landry, 1986; McArthur & Adamson, 1996; Mundy, Sigman, & Kasari, 1990), a group of children with extraordinary problems with the development of secondary intersubjectivity and language. Children with ASD have protracted periods before CJA emerges, if it emerges at all (Baron-Cohen, 1989). As with typically developing children, several studies have linked CJA to language development in children with ASD (Loveland & Landry, 1986; McArthur & Adamson, 1996; Mundy et al., 1990; Rollins & Snow, 1998). Because CJA is thought to provide the necessary infrastructure for language development in typical and clinical populations, finding a predictor to CJA would provide information on what drives language development via CJA earlier in infancy before 9 months of age, which could have clinical implications for the treatment of ASD. Theoretically, the identification of predictors to CJA could speak to the heavily-debated issues around the nature and origins of language development, whether language is environmentally influenced or solely biologically driven (see Greenspan & Shanker, 2004; Shanker & Greenspan, 2005 for a discussion).

Affect attunement (AA) is a good candidate for study as an environmentally influenced predictor of CJA because of the many theoretical accounts proposing an important developmental relationship between AA during caregiver-infant interactions and later development of CJA (Adamson & Russell, 1999; Greenspan & Shanker, 2004; Rochat & Striano, 1999; Shanker & Greenspan, 2005; Stern, Hofer, Haft, & Dore, 1985; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Trevarthen, 1993). AA has been used to describe a state of shared emotions between participants in a dyadic interaction (Stern et al., 1985). In this article, we examine the putative relationship between AA at 6 and 9 months of age and CJA at 12 months.

Many theorists have suggested that sharing experiences with others during early caregiver-infant face-to-face interactions provides a foundation for later social knowledge, including understanding others' intentions or intersubjectivity (Greenspan & Shanker, 2004; Hobson, 1993; Nicely, Tamis-LeMonda, & Grolnick, 1999b; Papousek & Papousek, 1991; Rochat & Striano, 1999; Shanker & Greenspan, 2005; Stern, 1995, 1999; Trevarthen, 1993). Around 2 months of age, infants begin to share experiences, affect, and emotions with others. Face-to-face interactions are predominant at this age and experiences are shared through sharing affect during dyadic interactions. In this view, the development of affective matching between self and others lay the foundations of infants' social knowledge (Greenspan & Shanker, 2004; Rochat & Striano, 1999; Shanker & Greenspan, 2005). Infants apply what they understand in dyadic situations (understanding the affects, feelings, and emotions of others) to the context of triadic situations, suggesting developmental synchrony between dyadic and triadic abilities (Adamson & Bakeman, 1985, Adamson & Russell, 1999; Greenspan & Shanker, 2004; Markova & Legerstee, 2006; Rochat & Striano, 1999; Shanker & Greenspan, 2005; Stern et al., 1985).

Stern et al.'s (1985) seminal work defined AA as "the performance of behaviors that express the quality of a shared affect state, but without imitating the exact behavioral expression of the inner state" (p. 251). AA was described as an amodal concept because affect matches often occurred across modalities (facial, vocal, or body movements). However, the intensity of infant-caregiver affect matches was almost always matched. Stern et al. viewed affect matches as substitutable expressions for the same internal state, and suggested that this contingent matching between perceived internal states communicates a shared experience. Further, they suggested that it is through these shared experiences that infants come to understand that others have emotions, and that others' emotions can be the same or different from their own. Stern et al. hypothesized that this rudimentary understanding of others later develops into a deeper and more sophisticated understanding of others or intersubjectivity.

Stern et al.'s (1985) work indicated that cross- and mixed-modality affect matches and intensity matching should be incorporated in measures of AA. Further, they suggested that the features of intensity and time alone account for the important features of AA and reflect the quality of attunement. Intensity has been hypothesized as an important feature that is matched in order to communicate a shared emotional experience essential for developing an understanding of others. From an emotion regulation perspective, it is possible that lower intensity positive AA may have a greater impact on the ability to learn CJA. For example, the higher-intensity levels of positive affect could inhibit the development of CJA because it corresponds to high arousal levels and dysregulation, whereas low-intensity positive affect could be the most important feature of AA to CJA because of corresponding well-regulated and well-modulated emotional states. Because different intensity levels of AA may promote or inhibit social-cognitive or self-regulatory development, they are important to measure and analyze separately. For this reason, in our current study, we pursued the question of whether time spent in different intensities of AA is related to CJA.

Methodologically, the existing microanalytic studies of AA have typically measured infant affect only (Adamson & Bakeman, 1985) or maternal responsiveness to infant affect (Feldman & Greenbaum, 1997; Nicely, Tamis-LeMonda, & Bornstein, 1999a; Nicely et al., 1999b). Therefore, the potential bidirectional nature of dyadic AA, when both caregivers and infants are actively engaged and responding to each other, has not been specifically studied. This is important when analyzing AA longitudinally, especially because the contribution of each member of the dyad may change over time as the infant develops more mature social-cognition.

Further, there is limited empirical evidence linking early episodes of infant-caregiver AA to later CJA utilizing a predictive design. Adamson and Bakeman (1985) studied infants' affective displays concurrently, during various engagement states including CJA, but did not analyze caregiver-infant matching from a dyadic perspective. Similarly, studies have found children with ASD to have deficits in displays of positive affect (Bieberich & Morgan, 1998; Joseph & Tager-Flusberg, 1997; Kasari, Sigman, Mundy, & Yirmiya, 1990; Shanker & Greenspan, 2002; Yirmiya, Kasari, Sigman, & Mundy, 1989) and deficits in attention with others (Joseph & Tager-Flusberg, 1997; Loveland & Landry, 1986; McArthur & Adamson, 1996; Mundy et al., 1990). It has been suggested that this disturbance in affect sharing may contribute to deficits in attention and these two constructs may be integrated in development (Greenspan & Shanker, 2004; Joseph & Tager-Flusberg, 1997; Kasari et al., 1990; Shanker & Greenspan, 2005). Nonetheless, as with studies of typically developing children, the predictive nature of the relationship was not explored.

The purpose of this prospective longitudinal study was to pursue the nature of the relationship between infant-caregiver (*dyadic*) AA at 6 and 9 months of age and infant CJA at 12 months of age, when CJA is more stable. In our investigation, we analyzed the contributions of both the caregiver and the infant to AA. Further, we examined AA at neutral, low, moderate, and high intensity levels. We hypothesized that low-intensity AA may facilitate an infant's coordination of attention between a caregiver and an outside entity because low-intensity AA episodes correspond to well-regulated and well-modulated emotional states, which may facilitate an infant's information processing capacity. On the other hand, higher-intensity AA may inhibit the development of intersubjectivity because of corresponding higher arousal states and dysregulation.

METHODS

Participants and Procedures

Thirty participants, consisting of 15 mothers and their typically developing infants, participated in this study. These dyads were drawn from the University's

Language and Communication Database Project as part of a larger prospective longitudinal study. All mothers were recruited by mail utilizing information obtained from a marketing firm. Infants were excluded from the study if they had medical complications at birth, any subsequent major illnesses, or had known developmental disabilities. Dyads came to the laboratory within 1 week of the infants' 6, 9, and 12 month birthdays. Laboratory visits included video-taped object-mediated mother-infant free-play sessions. Participants for the current study were selected based on the mother-infant dyads with a full complement of quality videos capturing mother-infant interactions at 6, 9, and 12 months of age.

All the mothers in the current sample were Caucasian and reported a high school level of education or greater (M = 16.13 years, SD = 1.88). Infants included 10 males and 5 females, and 9 first-born, 4 second-born, and 2 third-born children. All children were learning English as their first language and were not exposed to another language for more than 7 hours a week, except for one child who was exposed to Spanish via his nanny. All children were reported to be full-term (38-42 weeks gestation) and normal birth weight (≥ 2500 grams).

Data Collection

Mother-infant dyads were brought into the lab at 6, 9, and 12 months of age. At each age, mother-infant dyads were videotaped for 15 to 20 minutes during object-mediated free-play sessions. At 6 and 9 months of age, infants were seated in an infant seat with a tray for holding toys, and mothers were seated facing their infant. At 12 months, infants and mothers were seated on the floor. A standard set of age-appropriate toys was provided, and mothers were instructed to play with their infant as they typically would at home. A view of participants' faces, bodies, and surrounding toys were captured using split-screen video technology from two cameras located behind one-way mirrors on opposite sides of the room. The split-screen image was recorded on Hi 8 videotape and later converted to digital video with relatively no compression for later coding.

Affect Attunement Coding: A Three Phase Process

Five minutes of video were selected for coding on the basis of two criteria: (a) the ability to adequately see participants' faces and affective expressions for coding AA, and (b) periods of time in which mothers and infants were mutually engaged with each other (see mutual-engagement coding below). As often as possible, the best continuous 5 minutes at the 6 and 9 month time points were selected for coding. If the selection contained any time that faces were not viewable for coding, the corresponding viewable time was added to the end of the original selection in order to ensure exactly 5 minutes of codable time. The selection of codable interactions underwent three phases of coding in order to develop a dyadic measure of AA, which we termed *dyadic affect matching* in Phase 3. The phases of coding are described below. For all phases, continuous microanalytic coding occurred with quarter-second precision based on Feldman and Greenbaum (1997) because this is small enough to produce intensity-time contours but large enough to be reliable between coders.

Coding Phase 1: Mutual-Engagement

Mutual-engagement was coded using Bakeman and Adamson's engagement state coding procedures (Adamson, Bakeman, & Deckner, 2004; Bakeman & Adamson, 1984; Carpenter et al., 1998). Specifically, six engagement states were coded: *unengaged, onlooking, object, person, supported joint engagement,* and *coordinated joint engagement*. Each engagement state lasted at least 3 seconds. In order to utilize a mutually exclusive and exhaustive coding scheme, *cannot code* was also used to indicate times that were not codable due to a lack of information, such as when a participant was off-camera. This was a rare occurrence, and time was added at the end of the original selection to account for exactly 5 minutes of codable time.

AA requires dyads to be mutually engaged either face-to-face or with an object of joint focus. Therefore, the engagement state data were collapsed according to two categories: mutual-engagement (i.e., when AA was possible), and no-mutual-engagement (i.e., when AA was not possible). Three engagement states comprised periods of *mutual-engagement:* (a) *persons*—when dyads mutually participated in dyadic face-to-face interactions, including social games; (b) *supported joint*—when both the infant and mother were actively involved with the same object or outside entity; however, the infant was not coordinating his or her attention between the mother and object; and (c) *coordinated joint*—when infants coordinated their attention between both an object and their mother, representing CJA. The second category, *no mutual-engagement*, consisted of the following states: (a) *unengaged*—when infants were not engaged with anything at all, including their mother or an object; (b) *onlooking*—when infants watched and observed their mothers but were not physically or emotionally participating in any way; and (c) *objects*—when infants attended exclusively to an object and their mother did not participate in any way.

Coding Phase 2: Infant Affect During Mutual-Engagement

Infant affect was coded only during times of mutual-engagement described above in Phase 1. This decision was supported by Adamson and Bakeman's (1985) finding that infant affective expressions were more likely to occur during the states that we categorized as mutual-engagement when interacting with their mothers, than during the other states. Infants' affect was coded for valence (i.e., positive, neutral, and negative) and intensity of positive affect (i.e., low, moderate, and high) according to the following codes: *negative, neutral, low-intensity positive, moderate-intensity positive,* and *high-intensity positive affect*. In addition, two codes, *cannot-code* and *not-interpretable*, were used when there was not enough information to accurately determine one of the affect codes. Modality information (i.e., facial, body, vocal) was not separated due to the amodal nature of AA; however, multi-modal expressions tended to have higher perceived intensities than uni-modal expressions. Intensity of the whole affective expression was determined based on a multi-media coding scheme which was developed in order to accurately and consistently code affect intensity across infants.

The coding scheme was created using real digital video clips by grouping similar expressions across different infants, and by grouping similar intensities of varying expressions across different infants. As a result, an intensity-based affect-coding scale was created which was appropriate for 6- to 9-month-olds and calibrated across all infants. This inter-individual scale allowed for accurate representations of intensity that could be applied to all infants in the sample. The coding scheme manual (Greenwald & Rollins, 2007) was audio-visual and is not adequately expressed in words alone; however, a general description of each code is provided in Appendix A.

Coding Phase 3: Maternal Affect and Dyadic Affect Matching (AA)

Maternal affect and dyadic affect matching (AA) were coded together in the final phase of coding. Infant files from the second phase were used as the base file. Following the structure of infant affect, codes were virtually identical except a code for *comforting* was added. Therefore, mutual engagement[1] from Phase 1 was coded for maternal affect and dyadic affect matching according to the following codes: *comforting, cannot code, not-interpretable, negative, neutral, low-intensity positive, moderate-intensity positive,* and *high-intensity positive affect*. This method resulted in 72,000 total data points[2] for AA coding.

A multi-media coding scheme was developed specifically for maternal affect and dyadic affect matching. In order for the maternal affect scale to represent both maternal affect and dyadic affect matching, the coding scale was meticulously calibrated across all mothers and across infants to ensure accurate matching information. It was important to be calibrated across all mothers in order to accurately represent intensity information and show individual differences between mothers and dyads. In order to capture AA, it was of primary importance

[1]Transitional windows (2-seconds preceding and 1-second following mutually engaged states) were also coded for Phases 2 and 3. Window information was not used for analysis except to identify periods of affect-intensity matching at the beginning of mutually engagement states.

[2]Total data points for AA were computed based on the following calculations: 1) 5-minute session, at 60 seconds per minute, at .25-second intervals, equals 1200 data points per dyad per pass ($5 \times 60 \times 4 = 1200$); 2) AA coding consisted of 15 dyads, 2 passes (only passes 2 and 3 are utilized in the analyses), and 2 time-points which resulted in 72,000 data points ($1200 \times 15 \times 2 \times 2 = 72{,}000$).

to ensure that mothers were calibrated to their infants in order to code dyadic affect-intensity matching. Matches were defined as maternal expressions of similar overall intensity as their infant while allowing for a slightly higher intensity due to mothers' broader repertoire of affective behaviors. As it was mothers who had the broader repertoire of affective behaviors, the converse was not true, mothers and infants were not considered matched if their infants' intensity was higher. During coding, a final pass consisted of ensuring accurate matches between infants and mothers. The coding scheme manual (Greenwald & Rollins, 2007) was audio-visual and is not adequately expressed in words alone; however, a general description of each code is provided in Appendix B.

CJA Coding

CJA was measured at 12 months of age when CJA is more robust and stable in development (Bakeman & Adamson, 1984; Carpenter et al., 1998). The same process explained in the AA coding section was used to identify the best 5 minutes plus an additional surrounding 5 minutes of continuous mother-child interaction. A total of 10 minutes was utilized to be consistent with the CJA literature. CJA was coded with quarter-second precision according to the same microanalytic coding procedures used for AA and described below.

A shortened version of engagement state coding described under Phase 1 was used and consisted of collapsing all codes except *coordinated joint*. Coordinated joint engagement represents CJA and terms are used interchangeably. Following engagement state coding procedures and definitions, CJA was coded when the infant looked from an object to the mother's face and back to the same object (3-point triadic gaze pattern). CJA was also coded utilizing triadic communicative gestures or referential words of a shared nature such as "show" gestures or object labeling to share attention. In this coding system, CJA does not include supported joint engagement. In supported joint, the adult is responsible for the sharing of the attention, whereas in CJA the infant coordinates their attention between mother and object in a 3-point triadic gaze pattern. CJA measured in this manner best represents intersubjectivity and does not include dyadic 2-point gaze shifts between mother and object as used in studies of related but not coordinated joint attention skills (Mundy, Block, Delgado, Pomares, Van Hecke, & Parlade, 2007; Slaughter & McConnell, 2003). The CJA coding scheme resulted in 72,000 total data points[3] containing codes for *coordinated joint, not-CJA*, and *cannot code* (corresponding viewable time was added to the end of the selection to ensure exactly 10-minutes of coded time).

[3] Total data points for CJA were computed based on the following calculations: 1) 10-minute session, at 60 seconds per minute, at .25-second intervals, equals 2400 data points per dyad ($10 \times 60 \times 4 = 2400$); 2) CJA coding consisted of 15 dyads and 2 time-points which results in 72,000 data points ($2400 \times 15 \times 2 = 72{,}000$).

General Microanalytic Coding Procedures

Coding procedures for AA and CJA included coding the exact moment in which a code began (onset) and terminated at the exact moment a different code began (offset), creating timed-event sequences (Bakeman & Gottman, 1997). Offset times were excluded in the analysis because each offset time represented the next onset time and was included in the analysis for the next code. All coding schemes were mutually exhaustive and exclusive; therefore, every millisecond contained a related code throughout the entire video selection.

A customized computer program (Taber, 2006) was used to round each starting time to the nearest quarter-second. In addition, the program created a record for each quarter-second between each onset and offset time. This created episodes of accurate durations for capturing measures such as total duration per code and duration per episode with quarter-second precision. Further, this provided the ability to analyze AA intensity matches in a manner which accurately reflects the reciprocal back-and-forth nature of AA. Specifically, AA intensity matching measures were obtained by identifying each quarter-second in which the infant and mother had identical affect codes from Phases 2 and 3 at the same time or up to 2 seconds afterwards.

Measures

Percent ME-Time Matched at Each Intensity

The three phase coding procedure yielded measures of dyadic affect intensity matching (AA), at each intensity level (identical affect intensities expressed by both participants at the same exact time or up to 2 seconds afterwards). Furthermore, our AA measure was coded only during periods of mutual engagement. Because the total amount of time each dyad spent in mutual engagement (referred to as *ME-time*) differed across children, we calculated the *percent of ME-time* the dyad was matched at each level of intensity (neutral, low-, moderate-, and high-intensity positive AA). Negative valence was excluded because it was a rare event. This yielded four measures of AA used for analyses:

1. *neutral intensity AA*—percent of ME-time dyads spent matched at neutral intensity;
2. *low intensity AA*—percent of ME-time dyads spent matched at low intensity;
3. *moderate intensity AA*—percent of ME-time dyads spent matched at moderate intensity; and
4. *high intensity AA*—percent of ME time dyads spent matched at high positive intensity.

Mean Duration of CJA Episodes

The mean duration of CJA episodes was selected as the outcome measure, and was used to represent the stability of CJA at 12 months. CJA was calculated by taking the duration of each individual CJA episode demonstrated for a given dyad and computing an average. This reflects the average amount of consecutive time a 12-month old spent demonstrating CJA before shifting to a different state.

Inter-Rater Reliability

All coding was independently double coded by a second coder for 20% of the video data at each time point for each measure: mutual-engagement (AA Phase 1), infant affect (AA Phase 2), maternal affect and dyadic affect matching (AA Phase 3), and CJA. Sessions chosen for reliability coding were randomly selected among the set of non-training data, ensuring that sessions used for training or in the multi-media coding scheme were not utilized. Cohen's kappa statistic was calculated based on quarter-second data points, utilizing no error or tolerance window. Unlike other studies using similar methods (Adamson & Bakeman, 1985), this reflects the strictest interpretation of reliability because no error window was allowed and quarter-seconds are very small units of time for engagement state coding. Point-by-point comparison was utilized for mutual-engagement and CJA coding. Code comparisons for each segment were conducted for infant affect and maternal affect and dyadic affect matching. All individual and summary kappa statistics for all coding and phases were considered "almost perfect" or "substantial" according to Landis and Koch (1977). Inter-rater agreement reached $\kappa = .83$ for mutual-engagement (AA Phase 1), $\kappa = .85$ for infant affect (AA Phase 2), $\kappa = .77$ for maternal affect and affect matching (AA Phase 3), and $\kappa = .79$ for CJA.

Statistical Analyses

Descriptive statistics, correlation, and regression analyses were used to explore the relationship between dyadic affect-intensity matching measures at 6 and 9 months and the mean duration of CJA episodes at 12 months. All assumptions of regression (normal distribution, linearity, homoscedasticity, and normality of error variance) were meticulously checked. A significance level of .05 was used for all statistical tests.

RESULTS

Affect Attunement

Univariate statistics for each AA measure at 6 and 9 months are presented in Table 1. While dyads varied considerably in the amount of attunement at each intensity level, all dyads engaged in neutral, low, and moderate intensity

Table 1. Percent ME-Time Spent Demonstrating Dyadic Affect Intensity Matching at Each Intensity Level

	Variable	Min	Max	Skewness	Mean	*SD*
6 months	Neutral	0	62	.45	23.5	20.9
	Low-intensity	6	42	1.21	17.2	10.8
	Moderate-intensity	1	37	1.02	12.8	11.9
	High-intensity	0	37	3.55	3.8	9.5
9 months	Neutral	11	59	.26	32.9	14.8
	Low-intensity	7	29	.68	16.2	7.1
	Moderate-intensity	0	25	.37	10.6	7.6
	High-intensity	0	15	3.20	1.6	4

attunement at both ages with two exceptions. One dyad did not use neutral AA at 6 months and another dyad did not use moderate attunement at 9 months. In order from most often to least, neutral AA occurred the most (23.5 and 32.9% at 6 and 9 months, respectively), followed by low-intensity AA (17.2 and 16.2%), then moderate-intensity AA (12.8 and 10.6%), and high-intensity AA was fairly uncommon (3.8 and 1.6%). High-intensity AA was highly skewed at both ages, and not all dyads reached this high of intensity during AA.

Coordinated Joint Attention

All children demonstrated some CJA at 12 months. The *mean duration of CJA episodes* varied widely (M = 51.7, SD = 21.5, min = 17.2, max = 104.5, skewness = .95) ranging from 17 to 105 quarter-seconds (4.25 to 26.25 seconds) in length. One child was a clear outlier in mean duration of CJA. Without him, the mean CJA episode ranged from 17 to 78 quarter-seconds (4.3 to 19.50 seconds) with a mean of 47.9 quarter-seconds and a standard deviation of 16.4. There were no statistically significant relationships between the mean duration of CJA episodes at 12 months and the same measure at 9 months, maternal years of education, or maternal experience as measured by infant birth order and CJA. However, there was limited variability in the demographic data representing a homogeneous group of mothers.

Predictive Analysis: AA and CJA

The primary research questions under investigation were the effects of AA, as defined by the percent of ME-time dyads spent demonstrating affect-intensity matches (neutral, low-, moderate-, and high-intensity), on the stability of CJA at 12 months, measured by the mean duration of CJA episodes. First, correlation analyses between these AA variables and CJA were conducted to estimate associations, and to select AA variables for further investigation. Two significant correlations were found (see Table 2): a strong positive association between low-intensity AA at 6 months and CJA at 12 months (r = .634), and a strong negative relationship between moderate-intensity AA at 9 months and CJA at 12 months (r = –.649). Taken together these findings are consistent with our predictions that the direction of the relationship between AA and CJA is not the same across the various intensities in which affect can be matched.

Results from the regression analyses are reported in Table 3. The first three simple regression models included low-intensity AA at 6 months (M1), low-intensity AA at 9 months (M2), and moderate-intensity AA at 9 months (M3). Of these, only Models 1 and 3 were related to CJA at 12 months, explaining 40.2% and 42.2% of the variation respectively. As would be expected from the correlation analyses, above, low-intensity AA at 9 months was not related to CJA at 12 months (M2). Nonetheless, it was retained for multiple regression analyses to examine the combined effects of low-intensity AA at 9 months in combination with moderate-intensity AA at 9 months on CJA at 12 months (M4). In addition, we regressed CJA at 12 months on the main effects of low-intensity AA at 6 months and moderate-intensity at 9 months (M5). These models explained 62.5% and 60.4% of the variance in CJA at 12 months respectively. Models 4 and 5 are both parsimonious and taken together add a slightly different aspect to the relationship between AA and CJA. Both models demonstrate an association, on average, between dyads who demonstrated more frequent low-intensity AA (at 6 or 9 months) and less frequent moderate-intensity AA at 9 months with longer infant CJA episodes at 12 months. Model 5 indicates that low-intensity AA at 6 months of age uniquely predicts CJA, even when in the presence of moderate-intensity AA at 9 months which has a strong negative association with CJA. Model 4 indicates that low-intensity AA at 9 months predicts CJA only in combination with moderate-intensity AA at 9 months which continues to have a strong negative association with CJA.

Table 2. Correlations between Dyadic Affect Intensity Matching at Each Intensity Level at 6 and 9 Months and the Mean Duration of CJA Episodes at 12 Months

6 Months				9 Months			
Neutral	Low	Moderate	High	Neutral	Low	Moderate	High
–.458	.634*	–.242	.336	–.144	.411	–.649**	.253

*p < .05. **p < .01.

Table 3. Multiple Regression Building Table of Dyadic Affect Intensity Matching Variables Predicting the Mean Duration of CJA Episodes at 12 Months

	Low-Intensity 6 mo.		Low-Intensity 9 mo.		Moderate-Intensity 9 mo.		
Model	*B*	*SE B*	*B*	*SE B*	*B*	*SE B*	R^2
1	126.91*	42.90					.402
2			124.39	76.55			.411
3					–185.06**	59.78	.422
4			136.71*	53.63	–191.75**	50.20	.625
5	91.67*	39.06			–136.60*	55.34	.604
6	59.62	40.11	97.81	57.85	–158.70*	53.13	.685

$^{*}p < .05$. $^{**}p < .01$.

DISCUSSION

The results from this study suggest that low-intensity AA predicts the stability of CJA at 12 months. This finding supports theoretical accounts of the development of intersubjectivity. That is, the ability to share affects early in infancy lays the foundation for a deeper and more sophisticated understanding of others as intentional agents or intersubjectivity. However, our findings also extend the understanding of this relationship in important ways. We found that while well-attuned affect at low-intensities had a positive association with later CJA, well-attuned affect at moderate-intensities, when infants were 9 months, had a strong negative association with CJA at 12 months. That is, while low-intensity AA may promote the understanding of others' attention, moderate-intensity AA may have the opposite effect. Thus, when infants are 9 months of age, the direction of the relationship between AA and CJA differs, on average, by the intensity of the emotions being shared.

There are several plausible explanations for the negative relationship between moderate affect attunement at 9 months and CJA at 12 months. It could be simply a developmental phenomenon. Although all the children were typically developing with no cognitive deficits, the rate of social engagement from simple dyadic to triadic interactions may have differed among the children. Prior to 6 months of age, infants engage in dyadic face-to-face interactions that reflect well-balanced, reciprocal, and rhythmic exchanges of affect and emotions (Brazelton, Koslowski, & Main, 1974; Greenspan & Shanker, 2004; Shanker & Greenspan, 2005; Stern, 1985; Trevarthen, 1977, 1979). These dyadic interactions frequently contain lively moderate-intensity predictable routines, rhymes, tickle games, and body movements (Bruner, 1978, 1983). By 9 months, dyadic moderate-intensity shared interactions are less frequent in favor of triadic interactions involving objects and toys. Dyads that use more moderate-intensity AA at 9 months may be doing so because the infant is less advanced relative to other typically developing age-mates. Data from the current study, however, did not support this hypothesis.

An alternative hypothesis is that the intensity of AA observed at 9 months was influenced by the pattern of interaction between the infant and caregiver. By 6 months of age, infants have mastered complex upper body motor skills and are able to focus on distal objects within the immediate environment. A broad array of attentional options are now available, and infants spend increasing amounts of time focused on objects with no indication that they want to share the objects with the caregiver. Nonetheless, the infant-caregiver collaboration continues to expand to include triadic interactions that incorporate the object (Trevarthen & Hubley, 1978). Adamson and colleagues (Adamson & Russell, 1999; Bakeman and Adamson, 1984) described these early triadic interactions as *passive or supported joint engagement.* Infants are thought to be passive because they do not explicitly acknowledge their caregiver's contribution to the interaction by looking back at the caregiver and smiling. Caregivers may actively follow the child's focus of attention, thereby supporting social communication by expanding the child's solitary focus to include caregiver verbal and nonverbal information about the attentional target. Thus, from 6 to 10 months, triadic interaction involves the infant and caregiver jointly perceiving an object or an event towards which they both direct their actions (Tomasello et al., 2005). It may be that some caregivers are more skilled at supporting their infant's joint attention in calm interactions without over-arousing them. The relationship between intensity level at 9 months and CJA at 12 suggests that low-intensity AA promotes the understanding of others' attentions, changing the function of AA for children from understanding others' emotions to understanding others' attentions (also see Greenspan & Shanker, 2004 and Shanker & Greenspan, 2005 for a similar articulation of the relationship between changes in the role of AA and the development of the infants mind).

To elucidate the manner in which the caregivers in this study interacted with their infants, we graphed, for each dyad, the variables retained in multiple regressions Model 5 (M5) with the patterns of interaction that emerged from the data for each dyad (see Figure 1). We chose to graph the variables from Model 5 (M5) because low-intensity AA at 6 months and moderate intensity AA at 9 months both contributed unique variance to CJA at 12 months.

Figure 1 displays six graphs organized by pattern of interaction in descending order of CJA. It is noteworthy that some dyads used more than one pattern of interaction; however, each dyad could be classified as using one of the patterns described below. Because our measure of AA and CJA are in different metrics, each raw score was standardized using the means and standard deviations from the

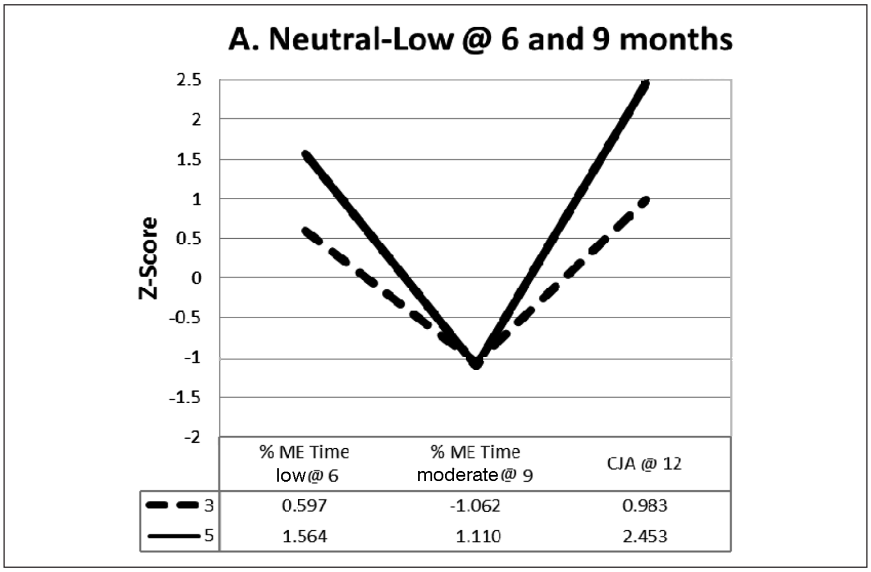

Figure 1A. Graph of regression Model 5 for each dyad by pattern of interaction.

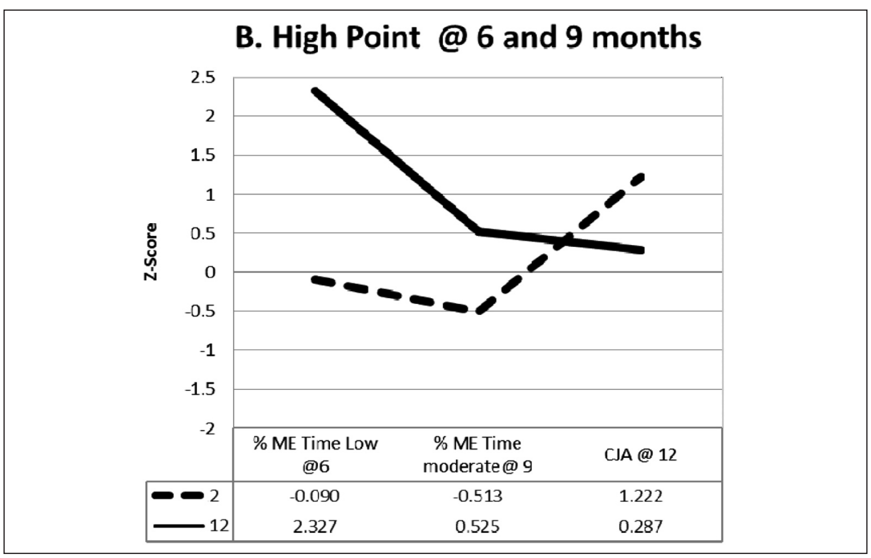

Figure 1B. Graph of regression Model 5 for each dyad by pattern of interaction.

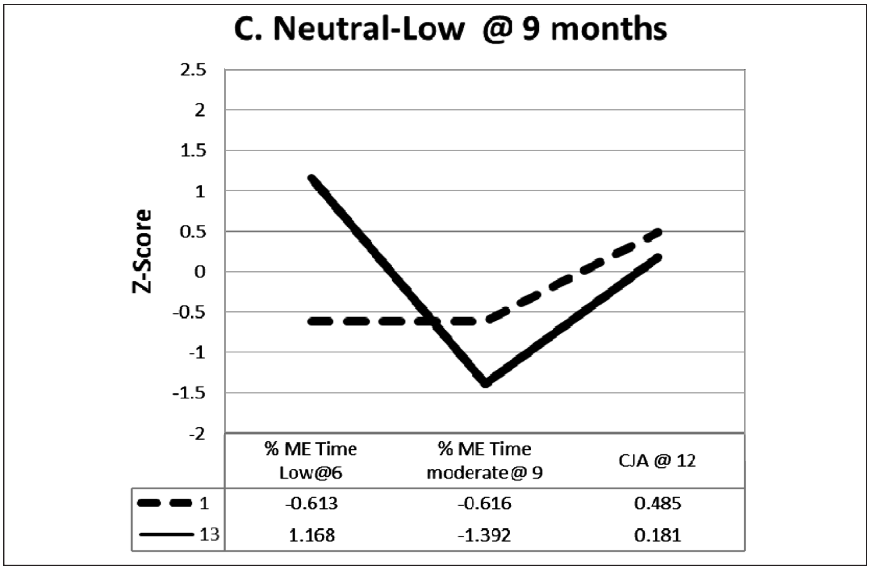

Figure 1C. Graph of regression Model 5 for each dyad by pattern of interaction.

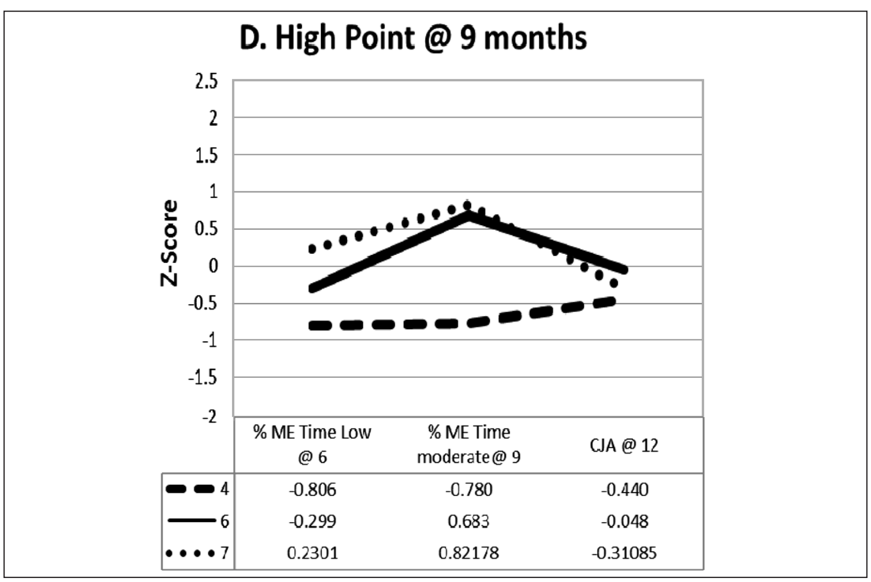

Figure 1D. Graph of regression Model 5 for each dyad by pattern of interaction.

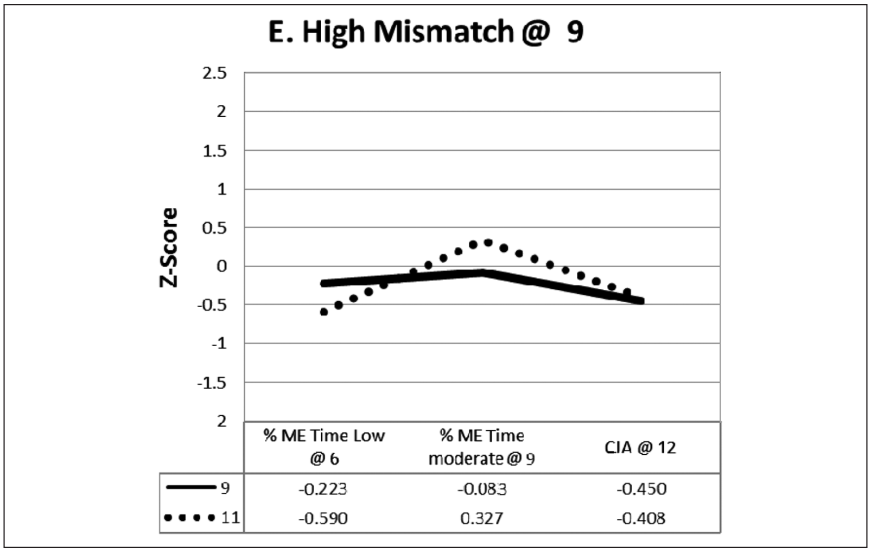

Figure 1E. Graph of regression Model 5 for each dyad by pattern of interaction.

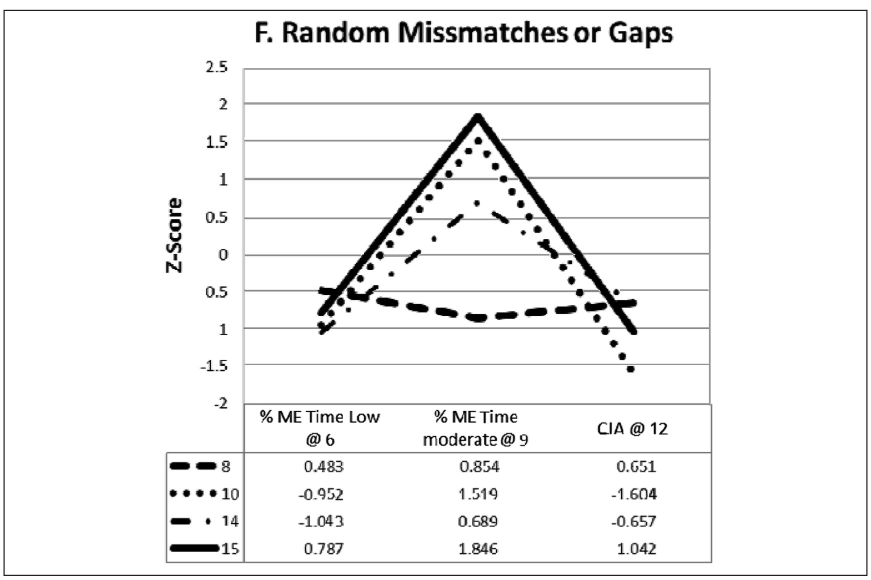

Figure 1F. Graph of regression Model 5 for each dyad by pattern of interaction.

15 dyads in this study (see Table 1). In this way, the standard scores for each measure could be presented for each set of dyads on a single graph (see Rollins, 1994, for a similar approach). A standard score (i.e., *z*-score) of 0 indicates that the dyad was average on a measure. A positive *z*-score indicates above average performance and a negative *z*-score indicates below average performance.

Patterns of Interaction

1. *Neutral-Low (NL) dyads:* The infants in dyads with the neutral-low pattern spent a large portion of time in neutral affect whereas their mothers co-regulated the interaction by maintaining low positive affect. Neutral-Low interactions were qualitatively different from interactions where the mother matched their infant's neutral affect. Mothers who co-regulated their infants affect using neutral-low interactional style appeared to use it as a strategy to keep their infants interested and engaged for longer periods of time. Dyads in Figure 1a used the Neutral-Low pattern at both 6 and 9 months. They scored high on low-intensity matching at 6 months and scored low on moderate-intensity matching at 9 months. Their average duration of CJA episodes at 12 months was among the highest in the sample. Figure 1c displays two dyads that co-regulated using the Neutral-Low pattern only at 9 months. These children's CJA were slightly above the mean at 12 months.
2. *High Point (HP) dyads:* High Point dyads engaged in co-regulated interactions in a manner that resembled the high-point or vitality contour described by Stern (1999). Some dyads engaged in a slow High Point while others engaged in a fast High Point. The slow High Point interactions were characterized by steady rise, peaking at low, moderate, or high intensity followed by a steady fall. This pattern typically contained low-intensity affect matching that was sustained for a few seconds on the way up or down. The fast High Point was similar to the slow version but the rate of rise and fall was very fast. This resulted in dyads that had relatively short average durations of affect matching episodes. Dyads in Figure 1b used the High Point pattern at both time points. Note that they scored higher on low-intensity matching at 6 months relative to their level of moderate intensity matching at 9 months. Consistent with what would be expected from the results of this study, these children had CJA above the mean at 12 months. The dyads in Figure 1d used the High Point style only at 9 months. Their low intensity matching at 6 months was comparatively depressed, and their CJA was slightly below average at 12 months.
3. *Higher Mismatched dyads:* Mothers in Higher Mismatched interactions tended to mirror their infant's affect and pace, but at a higher intensity. Higher Mismatches occurred when the intensity of the infant's affect was low or moderate (as compared to neutral as in the Neutral-Low combination). The Dyads in Figure 1e all used the Higher Mismatch pattern at 9 months. Dyad 9 used the Higher Mismatch interactional style at both ages whereas dyad 11

used the High Point interactional style at 6 months. Both of these infants had CJA slightly below the average at 12 months. Dyad 8 also used the Higher Mismatch interactional style at both ages, but that infant had below average CJA at 12 months (see Figure 1f).

4. *Random Mismatch dyads:* Mothers in random mismatch interactions used affect that was either higher or lower than their infants. Unlike Higher Mismatched interactions, Random Mismatch interactions did not appear to be used with a systematic co-regulation strategy. Figure 1f displays the profiles of dyads that were not well attuned. Dyads 10 and 14 used Random Mismatches or had large gaps in their interactions at both time points whereas dyad 15 used the High Mismatch interaction style at 6 months. Not surprisingly, these children had below average CJA at 12 months.

In summary, while there are individual differences in how dyads interact and attune to each other, the interactional styles of Neutral-Low and High Point both co-regulated interactions to achieve relatively more low-intensity AA at 6 months and relatively less moderate-intensity AA at 9 months. Three out of four of the dyads who used NL or HP at both 6 and 9 months (Figures 1a and 1b) had infants with CJA at 12 months that was approximately 1 standard deviation above the mean for the sample. Dyads that used the Neutral-Low co-regulation style at 9 months had infants with CJA at 12 months that was less than half a standard deviation above the mean, whereas dyads that used the HP co-regulation style at 9 months had infants with CJA at 12 months that was less than half a standard deviation below the mean (Figure 1d). On the other hand, dyads who were not well attuned (Figure 1f) at 6 and 9 months had infants with CJA at 12 month that was far below average. These results are striking when we consider that all of the children are typically developing and from middle class families. While unknown biological factors such as infants' temperament, neurological development, and individual developmental differences are certainly at play here, the influence of caregiver's style of interaction and ability to co-regulate their infant seems very strong.

This study suggests that there is a relationship between arousal level and attention, and that there may be an optimal level of arousal that facilitates understanding the attention of others. Prior to and during the emergence of CJA, caregiver-infant object-mediated interactions are rich in useful information, including but not limited to caregiver's contingent comments (Rollins, 2003), multi-modal motherese (Gogate, Walker-Andrews, & Bahrick, 2001; Rollins & Trautman, 2011; Trautman & Rollins, 2006), visual gaze referencing, gestural referencing such as maternal pointing (Mundy & Newell, 2007), interesting objects that are often multi-sensory, and shared multi-sensory emotional experiences during object play (Adamson & Bakeman, 1985). During these interactions, many mothers appear to promote and prolong their infants' attention to objects while simultaneously bringing attention to themselves as the social partner.

Given this rich set of information available to process, low-intensity AA may promote infants' understanding of others' attentions by providing an optimal learning environment for processing information and learning intersubjectivity. Successful maternal modulation of infants' emotions into a shared pleasurable low-key arousal state may reduce the cognitive processing load necessary for infants which allows them to focus on *both* objects and social interaction at the same time. Low-intensity AA may support and modulate infants' attention to objects in addition to social interaction. The more time spent in object-mediated caregiver-child interactions when arousal is low, the more the infant may be able to process surrounding environmental information. This is supported by recent findings that infant gaze monitoring positively predicted CJA, but only in a group of highly attuned mothers, as measured by maternal maintenance of attention and warm sensitivity (Legerstee, Markova, & Fisher, 2007). Further, results from our study support the idea that low-intensity emotion sharing is important to intersubjectivity. Optimal arousal states may create space in infants' minds for integrating two attention focuses—attention to a social partner and an object. This could be a very early form of multi-tasking which over-stimulating environments could inhibit.

Unlike low-intensity AA, moderate-intensity AA may inhibit processing external information. Higher emotional states may create a higher arousal level, resulting in less cognitive processing capacity for the rich set of information available during these interactions. It is quite possible that infants in these circumstances are over-aroused and less organized, and therefore cannot attend to their surroundings as well. As model 4 suggested, when time is spent at higher arousal states during the emergence of CJA at 9 months, a corresponding amount of time is not spent in the low-intensity state. Therefore, 9-month-olds who spend relatively more time in moderate-intensity and less time in low-intensity AA do not spend as much time in states that may optimize attention to both objects and their mothers simultaneously. In summary, moderate-intensity AA may be a less optimal arousal state for maintaining attention to inanimate objects and learning intersubjectivity at 9 months.

The positive predictive relationship between low-intensity AA (and not moderate-intensity AA) with CJA has important implications for intervention programs for children with ASD. Children with ASD have well documented problems with reciprocal responsiveness and shared affect with adults (Shanker & Greenspan, 2002; Wetherby, Watt, Morgan, & Shumway, 2007; Young, Rodgers, Rozga, Ozonoff, Hutman, & Sigman, 2011) as well as problems with joint attention (see Charman, 2003, for a review). Our findings that low-intensity affect attunement may be mediated by the pattern of caregiver-child interaction could offer insight into co-regulation strategies used when interacting with children with ASD. Caregivers and clinicians could enhance the therapeutic nature of their intervention strategies by co-regulating more low-intensity positive affect sharing and less moderate-intensity affect sharing. That is, their interactional strategies should be mindful not to over- or under-arouse the child. We propose that these well-regulated low-intensity interactions will set the stage for optimal availability and processing of social and linguistic information while simultaneously facilitating CJA. It is noteworthy that these recommendations are consistent with the *Social Communication, Emotional Regulation, and Transactional Support (SCERTS)* model (Prizant, Wetherby, Rubin, Laurent, & Rydell, 2006) and the *Developmental, Individual Difference, Relationship-based (DIR)* model (Greenspan & Wieder, 1998). Both of these models incorporate well regulated emotional interactions as a strategy for the development of attention and language.

This study contained a rich and plentiful data set (a total of 144,000 data points for AA and CJA combined) due to the intensive micro-analytic methods employed. However, the sample size was small and represented a homogeneous group of mothers; together these two factors limit the ability to generalize results to a broader population. On the other hand, the amount of data analyzed, the strength of the relationships found, and the theoretical explanations give credence to the value of this study and encourage replication to a larger sample. Overall, the results add to our understanding of a socially constructed attentional system and lend further support to the account that early AA relates to CJA. Of course, these correlations do not prove causality. However, the prospective nature of these cross-lagged correlations and regression analyses suggest that, for typically developing infants, intensity of AA at 6 and 9 months is associated with the development of CJA at 12 months.

Directions for Future Research

In addition to the need for replication on a larger sample of a more diverse group of caregivers and infants, studies including physiologic and other measures of emotion regulation could further speak to the accuracy of the theoretical ideas proposed. Further, both biological and environmental factors that impact the quantity or quality of caregiver-infant mutual engagement should be examined. From a truly dyadic perspective, infant factors such as infant temperament, sensory processing, and emotion regulation, and maternal factors such as post-partum depression and socioeconomic stressors should be examined in future studies of AA and social-cognitive development.

This study also has implications for including AA when examining other potential precursors to CJA. For example, gaze-following studies that involve measures of intensity-specific AA may shed light on the inconsistency of earlier gaze study findings. Although not well-replicated, early forms of gaze following have been proposed as an early sign of understanding others' intentions (Morales, Mundy, & Rojas, 1998). Some have suggested that gaze following is learned associatively (Corkum & Moore, 1995; Moore, 1998), while others have demonstrated that it is only achievable when objects are in the infant's visual field

(Butterworth & Cochran, 1980), and still others have shown that gaze following is not used to gain information with others until 10 months of age (Brooks & Meltzoff, 2005). Regardless, perhaps low-intensity AA during moments of maternal eye gaze at objects may make gaze following achievable. It is possible that gaze following is an unreliable measure at this age because it is dependent on the presence or degree of low-intensity AA. In other words, gaze following may be more achievable and meaningful to infants if they are already in a low-intensity shared emotional state.

Summary

Findings in this study both support and extend the theory regarding a predictive relationship between AA and intersubjectivity. Shared low-intensity emotional states, during caregiver-infant object-mediated interactions, support the development of attention before and during the emergence of CJA. The function of early AA may shift from understanding others' emotions to understanding others' attentions during object-mediated mutual engagement. Pleasurable well-modulated low-intensity AA appears to enhance infants' processing capacities for learning intersubjectivity during the emergence of CJA at 9 months; whereas moderate-intensity AA may impede the later stability of CJA.

APPENDIX A
Written Summary of the Infant Affect Coding Scheme (Phase 2)

The following coding scheme was audio-visual and is not adequately expressed in words; however, a brief description of each code is provided below. Please note that all codes occurred during periods of mutual engagement (from Phase 1).

Neutral Affect. Affect has neither a positive or negative underlying emotional tone.

Low-intensity Positive Affect. Affective expression of positive valence and low intensity (e.g., small smile; low-key enjoyment; very slight smile; small smile with slight vocalization; slight bouncing of legs).

Moderate-intensity Positive Affect. Affective expression of positive valence and moderate intensity (e.g., big smile with jaw ajar; big smile with vocalization; big smile and bouncing; slight smiling with big body affect; really excited body movements).

High-intensity Positive Affect. Affective expression of positive valence and high intensity (e.g., smiling and giggling with big bouncing; deep laughing; loud high-pitched squealing in excitement; really excited body movements and smiling).

Negative. Affective expression of negative valence of any intensity (e.g., crying; whining; screaming out of frustration; pout or frown).

Cannot-code was used when the face or body was obstructed enough that an accurate code could not be given. In these relatively rare cases, mutual-engagement time was added to the end of the selection in order to capture an identical amount of mutual engagement present in the original selection and code for affect accordingly.

Not-interpretable was used for emotional expressions that were impossible to interpret in valence, such as mixed negative and positive expressions.

APPENDIX B
Written Summary of the Maternal Affect and Dyadic Affect Matching Coding Scheme (Phase 3)

The following coding scheme was audio-visual and is not adequately expressed in words; however, a brief description of each code is provided below. Please note that all codes occurred during periods of mutual engagement (from Phase 1).

Neutral Affect. Affect has neither a positive or negative underlying emotional tone.

Low-intensity Positive Affect. Affective expression of positive valence and low intensity (e.g., smile; small smile with low vocal affect; inquisitive face with low vocal affect).

Moderate-intensity Positive Affect. Affective expression of positive valence and moderate intensity (e.g., big smile with sing-song voice; big smile with exaggerated vocal intonation; loud and fast voice with highly varied intonation; giggle; smile with soft vocal affect and gentle touch to child; moderately dramatic peek-a-boo and excited face; unique fun facial movements).

High-intensity Positive Affect. Affective expression of positive valence and high intensity (e.g., laughing loudly; squealing with big eyes and head tossed back; sharp and dramatic touching to child with expressive face and vocal marking; side-to-side rocking while bobbing head and smiling large; facially and vocally dramatic peek-a-boo; vibrating toy on child's face and squealing; laughing with rising intonation).

Negative. Affective expression of negative valence of any intensity (e.g., disapproving or reprimanding vocal tone; rolling eyes out of frustration).

Comforting. Affective expression such as sympathy or empathy which is used to comfort infants during times of distress or negative affect.

Cannot-code was used when the face or body was obstructed enough that an accurate code could not be given. In these relatively rare cases, mutual-engagement time was added to the end of the selection in order to capture an identical amount of mutual engagement present in the original selection and code for affect accordingly.

Not-interpretable was used for emotional expressions that were impossible to interpret in valence, such as mixed negative and positive expressions.

ACKNOWLEDGMENTS

The authors would like to thank: the children and families who participated in the study; Robert Stillman, Margaret Owen, and Melanie Spence for their input; James Taber for creating a customized computer program; and Rachel Wehner and Emily Connery for their assistance in coding and reliability.

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