The Official Journal of the International Society on Infant Studies
Infancy

Infancy, **18**(4), 490–515, 2013

ISSN: 1525-0008 print / 1532-7078 online
DOI: 10.1111/j.1532-7078.2012.00136.x

WILEY Blackwell

Dyadic Interaction: Greater than the Sum of its Parts?

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The study of dyadic interaction plays a major role in infancy research. To advance conceptually informed measurement of dyadic interaction and integration across studies, we examined factor structure of individual parents' and infants' measures and dyadic measures from face-to-face interactions in two samples of 6-month-old infants and their parents: mothers from a demographically heterogeneous sample (N = 164), and mothers and fathers

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($N = 156$) from a Caucasian middle-class sample. Results suggested that a) individual and dyadic measures, and parents' and infants' behaviors contribute independent information, b) measures of both valence and process are needed, c) there are context-general and context-specific qualities, and d) structure of dyadic interaction is more similar among mother–infant dyads from independent samples than between mother–infant and father–infant dyads within the same sample. Future research should use multiple measures incorporating valence, temporal processes, contextual influences, and behaviors of individual partners along with dyadic measures to adequately assess the quality of dyadic interaction.

DYADIC INTERACTION: GREATER THAN THE SUM OF ITS PARTS?

Theories (e.g., Gianino & Tronick, 1988; Stern & Gibbon, 1980; Tronick, 2005) propose that parents and infants respond to each other's behaviors during face-to-face interactions such that emergent qualities of dyadic interaction are greater than the sum of the individual partners' behaviors, what Tronick (2005) calls "dyadic expansion." A methodological challenge in studying dyadic interaction has been how to quantify these qualities, with considerable variability in the measures that have been used to assess dyadic interaction (De Wolff & van IJzendoorn, 1997) and numerous inconsistencies labeling and defining dyadic measures (Harrist & Waugh, 2002).

First, although measures of the dyad and measures of individual behaviors observed within dyadic interaction are conceptually distinct, it is unclear how to empirically distinguish the two types of measures and no consensus in the field as to methods for doing so. Indeed, we may ask whether it is possible to assess independent measures of individual behavior when observed within dyadic interaction because individual behavior will be influenced to some degree by the dyadic context. Consider studies that purport to measure one partner's behavior (e.g., maternal sensitivity, infant responsiveness), but acknowledge that the measure incorporates aspects of the other partner's behavior when, for example, one must take into account infants' behaviors to determine whether parents are behaving sensitively. Furthermore, measures of the dyad technically require computation of a correspondence between two sets of individuals' behaviors (Kenny, Kashy, & Cook, 2006), although many researchers have used a single global rating that subjectively takes into account behaviors of both individuals (e.g., Criss, Shaw, & Ingoldsby, 2003; Harrist & Waugh, 2002). Therefore, even though conceptually distinct, there are methodological complexities in trying to distinguish dyadic and individual measures when assessed in dyadic interaction.

Second, it is common for research to conflate measures of valence with the quality of dyadic interaction, assuming, for example, that positive affective behaviors indicate a higher-quality, more organized interaction in which the partners are having a mutually enjoyable experience. This is a conceptual and methodological issue similar to that affecting the construct of individuals' emotion regulation (Cole, Martin, & Dennis, 2004).

Third, little research has examined whether qualities of dyadic interaction are similar or distinct across contexts that present different demands. Theoretically, the way in which a dyad interacts is a stable, consistent property of the dyad but this characteristic style of dyadic interaction may also vary in response to contextual demands (e.g., Moore, Cohn, & Campbell, 1997). For example, in contexts that elicit negative affect from infants, if partners adapt their behaviors according to the same "rules" that they use to adapt to each other's behaviors in contexts that elicit positive affect, then we may see valence differences but not process differences in measures of dyadic interactions across contexts.

Fourth, the majority of studies on dyadic interaction have been conducted with mothers. Thus, we do not know whether the qualities and structure of dyadic interactions are similar between mothers and fathers. Although there is stability in infants' and parents' behaviors across mother–infant and father–infant interactions from the same families (e.g., Forbes, Cohn, Allen, & Lewinsohn, 2004), father–infant interactions are typically less positive, involve more physical play, are more unpredictable, and are characterized by the sudden buildup of high intensity emotional peaks (e.g., Braungart-Rieker, Garwood, Powers, & Notaro, 1998; Feldman, 2003; Forbes, et al., 2004). Therefore, there could be both similarities and differences in the quality and structure of dyadic interactions involving fathers and those involving mothers.

The current study

This study was a secondary data analysis of parents' and infants' behaviors during the Face-to-Face Still-Face Paradigm (FFSFP; Tronick, Als, Adamson, Wise, & Brazelton, 1978), a procedure that experimentally disrupts interaction between the parent and infant. After an initial period of normal play (NP), parents are instructed to become unresponsive to their infants and then to re-engage infants during a reunion period (RE). Infants are typically more negative and less positive during RE than during NP, suggesting context-specific demands (Adamson & Frick, 2003), making this procedure appropriate to use to examine potential contextual differences in the quality and structure of dyadic interaction. A set of measures of individual parents' and infants' behaviors and dyadic measures were computed from available microcoding of affect and gaze during the NP and RE episodes of the FFSFP and were factor analyzed. The measures were selected because they have been used in previous research, are theoretically and empirically linked to correlates of dyadic interaction, and represent the range of dimensions that theoretically make up the construct (individual, dyadic, affective valence, temporal process). Descriptions of the measures (in italics) used in the current study follow with representative examples from prior research.

INDIVIDUAL AND DYADIC MEASURES OF PARENT–INFANT INTERACTION

Individual measures

The amounts of time parents and infants display *Positive Affect, Negative Affect,* and *Gaze Away* from their social partners have been used in studies to assess various effects, including infant regulation within dyadic interaction (e.g., Stifter & Moyer, 1991) and the affective quality of parent–infant interaction (e.g., Campbell, Cohn, & Meyers, 1995). For example, mothers with chronic depression and their infants were more negative than other mothers and infants, suggesting an interaction that is less mutually enjoyable (Campbell et al., 1995). Infants' *Latency to Positive* and *Negative* behaviors in face-to-face interaction have been found to be associated with infants' self-regulation and the quality of parent–infant relationships (Messinger & Fogel, 2007; Messinger, Fogel, & Dickson, 2001). How often parents and infants reach a peak level of positive engagement (*Peak Positive Rate*) and the average duration of these peaks (*Peak Positive Duration*) have been found to indicate the ability to sustain positive arousal before needing to regulate affective states (e.g., Feldman, 2003, 2007). This set of measures of individual parents' and infants' behaviors during dyadic interaction has been widely used in the parent–infant literature and has consistent associations with developmental outcomes.

Dyadic measures

Three dyadic measures were included that met the criterion of being computed as the correspondence between sets of two individuals' behaviors (Kenny et al., 2006). Lower levels of *Matched Affect,* the degree to which parents and infants simultaneously display the same affective expressions, have been found to be related to greater physiological arousal and atypical vagal tone reactivity in infants interacting with mothers (Moore & Calkins, 2004). In other work, lower matched positive and higher matched negative affect have been associated with maternal depression (Field, Healy, Goldstein, & Guthertz, 1990), suggesting that assessing degree of matching without incorporating valence is insufficient when attempting to assess the quality of dyadic interaction. *Synchrony,* the degree to which partners change affective expressions in concert with each other, predicts self-regulation and compliance at 2, 4, and 6 years of age (Feldman, Greenbaum, & Yirmiya, 1999) and fewer behavior problems at age two (Feldman, 2007). Dyadic *Flexibility* refers to a lack of rigidity and an interaction in which partners are not stuck in one pattern of behaviors. Flexibility indicates movement among dyadic states, suggesting a process of mismatch and repair characteristic of effective mutual regulation (Tronick, 2005). Like synchrony, flexibility is a measure of the temporal coordination of two individuals' behaviors, regardless of valence but is not organized sequentially as is synchrony. Dyadic flexibility has been found to be related to positive parent–child interactions and adaptive outcomes in children and adolescents (Granic, Hollenstein, Dishion, & Patterson, 2003; Hollenstein, Granic, Stoolmiller, & Snyder, 2004; Lunkenheimer, Olson, Hollenstein, Sameroff, & Winter, 2011). Of note, greater flexibility in father–child interaction at age three was associated with higher levels of externalizing at age five, whereas greater flexibility in mother–child interaction was associated with lower levels of externalizing. These findings suggest that children respond differently to patterns of contingency with mothers and fathers and that degree of dyadic flexibility alone may be an insufficient measure to assess relevant qualities of dyadic interaction.

Questions and predictions

We used exploratory factor analysis (EFA) to examine the structure of relations among measures that have been used in research on dyadic interaction. Although analyses were exploratory, we made several predictions based on theory and prior research.

Do individual and dyadic measures add independent information about the quality of dyadic interactions? How are individual and dyadic measures related?

Based on the theory of dyadic expansion that dyadic interaction can be conceptualized as more than a sum of its parts (Tronick, 2005), we expected that dyadic measures would load on factors distinct from individual parents' or infants' measures. Although, theoretically, the prediction seems obvious, there is little empirical work that has explicitly examined relations between dyadic measures and measures of individual behaviors within parent-infant interaction. In addition, we expected that parents' and infants' individual measures would load on the same factors, reflecting the bi-directional nature of the interactions (e.g., Cohn & Tronick, 1988).

How is valence of affective behaviors related to temporal processes in dyadic interaction?

Based on a conceptualization of process as distinct from affective valence or content (e.g., Cole et al., 2004), we expected that measures of valence (e.g., amount of positive and negative affect, peak positive rate and duration, latency to positive or negative affect) and process measures (synchrony, flexibility, matched affect) would load on separate factors. Because parents are positive most of the time when observed interacting with their infants in the FFSFP, if factors distinguished by valence did emerge, we expected those to be characterized by measures of infants' behaviors.

Are qualities of dyadic interaction common across contexts that elicit different types of individuals' affective behaviors?

We expected that there would be factors common to and factors distinct to the NP and RE episodes based on a theoretical conceptualization of interactive style as a stable property of a dyad that also adapts to contextual demands (e.g., Moore et al., 1997). This issue is related to the question whether processes of dyadic interaction are distinct from valence. For example, because infants are typically more negative and less positive in the RE relative to the NP episode, would affective valence change the structure of the interaction? This could occur if infants' affect were driving the organization of the interaction but might not if parents adapted their behaviors according to the same "rules" or patterns that they used to adapt their behaviors to their infants' behaviors in other contexts.

Are qualities of dyadic interaction similar between mother–infant and father–infant dyads?

Prior research regarding stability and change in infants' and in parents' behaviors across mother–infant and father–infant interactions from the same families (e.g., Forbes et al., 2004) and in research finding different patterns of synchrony in mother–infant and father–infant interactions (Feldman, 2003, 2007), suggested we could find both similarities and differences. Therefore, analyses were exploratory and we did not make specific hypotheses.

METHODS

Participants

Data from two existing research programs were used to construct three data sets for factor analyses. The first data set was from a sample of mothers ($N = 164$) and their healthy 6-month-old infants (51% male) recruited by the Durham Child Health and Development Study (DCHD; P.I.'s M. Cox and S. Resznick) for whom behavioral data were available for mothers and infants during the NP and RE episodes of the FFSFP. Most infants were first-born (56%) or second-born (29%). Mothers ranged in age from 18 to 40 with an average age of 28.3 years. The DCHD sample included approximately equal numbers of African American (57%) and Caucasian (43%) mothers recruited from urban and rural communities. The majority (71%) were in two-parent families. Mothers' annual income ranged from less than $1,000 per year (12%) to $50,000 or more per year (13%) with half of the families (52%) recruited to be below 200% of the federally established poverty level. Below and above poverty families were approximately equally distributed between African American and Caucasian participants. With respect to education, 13% of mothers had no high school degree, 43% had a high school education, 11% had some college or vocational school, and 33% had a 4-year degree or higher.

The second research program included mothers and fathers from the same families ($N = 156$) and their healthy 6-month-old infants (48% male) participating in a study of infant development (Infant Development Study [IDS]; P.I., P. Lewinsohn). One parent from participating families in the IDS was drawn from a longitudinal study of individuals assessed during adolescence who were followed into adulthood (Lewinsohn, Hops, Roberts, Seeley, & Andrews, 1993). All infants were first-borns. In the IDS sample, mothers ranged in age from 17 to 37 years ($M = 26.0$, $SD = 2.42$) and fathers ranged in age from 22 to 40 years ($M = 27.5$, $SD = 3.33$). The majority of mothers (94%) and fathers (87%) were Caucasian. The families were predominantly middle-class with an average annual income greater than $30,000, ranging from less than $5,000 per year (3%) to $50,000 or more per year (22%). With respect to education, 53% of mothers and 52% of fathers had a high school education, and 46% of mothers and 45% of fathers had a 2-year or 4-year college degree or higher. For the purposes of the current study, two data sets were created from the IDS sample, one containing mother–infant interactions (IDS-M), the other containing father–infant interactions (IDS-F).

The IDS sample was recruited and studied during the mid-1990s. The DCHD sample was recruited in the early 2000s. Thus, we did not expect there to be major cohort differences (e.g., use of day care) in the samples.

Procedures

Parent–infant FFSFP

For both the DCHD and IDS studies, the FFSFP was conducted during a laboratory visit. Parents placed infants in an infant seat and sat in a chair directly in front of the infants and were given instructions for each episode. In the DCHD study, each episode was 2-min in length. Interactions were video recorded using two cameras, and video output was combined using a split-screen generator. Videos were digitized and interactions were coded from digitized videos. In the IDS study, the majority of observations of mother–infant interactions took place on the same day as father–infant interactions, with parent order counterbalanced. Each parent–infant dyad was observed in a modified version of the FFSFP, including a 3-min NP episode, a 40-sec game of peek-a-boo, a 2-min still-face episode, and a 2-min RE episode. Interactions were recorded using two video cameras with output to separate videotapes.

Coding affective behaviors

The same coding system was used in both studies, and the first author was involved in coding and/or in training coders for both studies, providing consistency in procedures across the data sets. Different coders were assigned to code parents' and infants' behaviors and mother–infant and father–infant interactions. Facial affect (positive, neutral, or negative) and direction of gaze (toward or away from partner) were coded at 1-sec intervals. Positive affect was coded if the individual smiled and negative affect was coded if the individual appeared sad or angry (e.g., frowned, corners of mouth turned down). If coders were unable to see infants' or parents' faces, behavior was coded as missing. In both studies, to assess inter-observer agreement, twenty percent of the interactions were selected randomly and coded by a second coder. Agreement was calculated as coders observing the same behavior within 1-sec. In the DCHD study, kappas for parents' and infants' affect and gaze ranged from 0.83 to 0.90. In the IDS study, kappas ranged from 0.71 to 0.83.

Following prior research (e.g., Cohn & Tronick, 1988; Moore & Calkins, 2004), to assess each individual's degree of positive engagement at each second of the interaction, information from affect and gaze was combined to derive a scaled score of positive engagement on a 6-point scale (i.e., a value of 1 was assigned if the individual displayed negative affect and gaze away, 2 if negative affect and gaze toward partner, 3 if neutral affect and gaze away, 4 if neutral affect and gaze toward, 5 if positive affect and gaze away, and 6 if positive affect and gaze toward). This method yielded a score for each infant and for each parent at each second that represented the degree of positive engagement displayed by the individual at that second with a 1 representing peak negative disengagement and a 6 representing peak positive engagement. In this sample, affect and gaze were correlated, $r = .24$, $p < .05$.

Each parent's and infant's time series of positive, negative, and gaze codes assigned by coders and the calculated positive engagement scores were used in the computation of individual and dyadic measures. If greater than 25% of the behavior codes were missing for either member of a dyad, the individual and dyadic variables computed from those data were considered unreliable and were not included in analyses. Across all three data sets, on average, 12.0% percent of the data were dropped because of this constraint. Measures were computed separately for the NP and RE episodes.

Computation of individual measures

Distributions of variables were examined for non-normality and transformed appropriately. Outliers were identified and set to the highest or lowest values of non-outlying data points.

Positive affect, negative affect, and gaze away

The total number of seconds spent displaying positive or negative affect and looking away from partners was computed for each parent and each infant separately. Only *Positive Affect* was retained for parents as they rarely displayed negative affect or looked away from infants. Variables were expressed as percentages of total interaction time. *Latency to Peak Positive and Latency to Peak Negative*. The number of seconds was computed from the start of the episode to the first instance of peak positive engagement (positive engagement score = 6) and first instance of peak negative (dis)engagement (positive engagement score = 1). The majority of parents showed extremely short latencies to peak positive engagement and rarely showed negative affect, so latency variables were computed for infants only. *Peak Positive Rate* was computed as the number of bouts of discrete displays of peak positive engagement for each infant. Any sequence of one or more consecutive seconds of peak positive engagement was considered a single "peak." If two time points at peak positive engagement were separated by up to 2 sec of missing infant data, they were considered to be part of the same peak. The total number of peaks was calculated across each episode and standardized by dividing by the length of the episode, resulting in a peaks-per-minute metric. Parents tended to remain positive for long periods of time so there was insufficient variability, and this variable was retained for only infants. *Peak Positive Duration* was calculated for both parents and infants. The duration of a peak was determined by the number of consecutive seconds at peak positive engagement. Up to 2-sec of missing data between two positive peaks were considered part of the same peak. The median duration was used to index average peak duration of positive engagement because the distribution of peak durations for many individuals was highly skewed.

Computation of dyadic measures

Matched affect

Parents' and infants' affect codes (positive, neutral, negative) were compared at each second and a code set to 1 if affect was identical or 0 if not. The total number of seconds in which parent and infant affect matched was calculated for each dyad and expressed as a percentage of valid episode length. *Synchrony* was computed as the square of the Pearson cross-correlations between the time series of parents' and infants' second by second positive engagement scores (ranging from 1 to 6 as described earlier). *Flexibility*. Following prior research (Granic et al., 2003; Hollenstein et al., 2004), three variables indexing flexibility were calculated for each dyad using GridWare software version 1.1 (Lamey, Hollenstein, Lewis, & Granic, 2004) based on parents' and infants' positive engagement scores (ranging from 1 to 6). The state space for the intersection of parent and infant states of positive engagement was a matrix of 36 cells (six parent by six infant) with each cell of the matrix representing a possible joint parent-infant state (e.g., parent = 1 infant = 1; parent = 1 infant = 2, parent = 1 infant = 3, etc.). *Cell Range* was computed as the number of cells out of the possible 36 that a dyad occupied during at least 1-sec of the interaction. Theoretically, the minimum was 1, if neither the parent nor the infant changed behavior, and the maximum was 36, if all possible parent states occurred at least once with all possible infant states. *Transitions* was computed as the number of changes among the cells as the dyads moved from one dyadic state to another, divided by the total interaction length, indexing the percentage of time the dyad changed states of positive engagement. *Dispersion,* a measure of how evenly the dyadic states were spread across all possible states, was calculated as the sum of the squared proportional duration of time spent across all cells, corrected for the number of cells and then inverted (Hollenstein et al., 2004). The variable ranges theoretically from 0, if the parent and infant remained in the same cell for the entire time, to 1, if the parent and infant spent an equal amount of time in each of the 36 cells.

RESULTS

Preliminary analyses

Descriptive statistics for variables used in the factor analyses are presented in Table 1 with significant differences between data set means as calculated by ANOVAs indicated. Because of differences between the DCHD and IDS procedures for conducting the FFSFP (addition of a peek-a-boo game in the IDS study), we looked for patterns among the mean differences in the data sets. Because over half of the differences were in variables measured in the NP episode, which occurred prior to the peek-a-boo game, the differences were more likely due to coding procedures rather than the addition of the game. The traditional still-face effect was observed in both studies, with comparable levels of positive (6%, 7%, and 7% for the DCHD, IDS-M, and IDS-F data sets respectively) and negative (16%, 17%, and 13%) affect, suggesting the addition of the peek-a-boo game did not affect the validity of the paradigm.

Because of the large number of variables and because some dyads had missing data for one or more variables, the bivariate correlation matrix was computed using pairwise deletion. With one exception, *Latency to Peak Negative* in NP, each variable correlated to a moderate degree (r's $> .30$, all p's $< .05$) with at least three other variables in two of the three data sets, indicating that the variables shared partially overlapping variance and were appropriate for factor analysis.

Exploratory factor analyses

Three separate EFAs were conducted on the data sets: DCHD (mother–infant dyads), IDS-M (mother–infant dyads), and IDS-F (father–infant dyads). Infant *Positive Affect* during RE and *Negative Affect* during NP were not included in the factor analyses because correlation matrices that included both *Positive* and *Negative Affect* within the same episode were singular, indicating that one of the variables introduced redundant information to the matrix. Therefore, only the conceptually salient affect for each episode was included.

TABLE 1
Descriptive Statistics for Variables Included in Factor Analyses

	Data set			
	DCHD	*IDS-M*	*IDS-F*	*Mean differences (p < .05)*
Infant measures				
% Positive affect NP	0.21 (0.19)	0.25 (0.21)	0.22 (0.19)	DCHD > IDS-F
% Negative affect RE	0.24 (0.31)	0.23 (0.31)	0.18 (0.29)	DCHD > IDS-M > IDS-F
% Gaze away NP	0.59 (0.22)	0.54 (0.23)	0.54 (0.24)	*ns*
% Gaze away RE	0.51 (0.24)	0.53 (0.25)	0.55 (0.25)	*ns*
Latency positive NP	32.49 (38.56)	29.25 (42.93)	32.40 (44.95)	*ns*
Latency negative NP	94.73 (41.91)	111.22 (67.92)	109.65 (68.73)	*ns*
Latency positive RE	31.88 (37.64)	20.12 (23.29)	22.29 (25.16)	DCHD > IDS-M
Latency negative RE	52.01 (44.99)	38.67 (28.17)	42.96 (28.32)	DCHD > IDS-F, IDS-M
Positive rate NP	2.37 (1.72)	2.63 (1.73)	2.74 (2.05)	*ns*
Positive rate RE	2.05 (1.78)	2.60 (2.07)	2.75 (2.33)	IDS-F > DCHD
Positive duration NP	2.39 (1.84)	2.57 (1.89)	2.43 (1.72)	*ns*
Positive duration RE	2.81 (2.57)	2.13 (2.00)	2.45 (2.47)	*ns*
Parent measures				
% Positive affect NP	0.69 (0.26)	0.58 (0.22)	0.51 (0.22)	DCHD > IDS-M > IDS-F
% Positive affect RE	0.60 (0.27)	0.51 (0.24)	0.52 (0.26)	DCHD > IDS-M
Positive duration NP	6.75 (3.86)	5.16 (3.10)	4.53 (2.72)	DCHD > IDS-F
Positive duration RE	5.85 (3.71)	5.15 (3.13)	5.22 (3.33)	*ns*
Dyadic variables				
% Matched affect NP	0.43 (0.22)	0.50 (0.18)	0.53 (0.18)	IDS-F, IDS-M > DCHD
% Matched affect RE	0.38 (0.24)	0.42 (0.23)	0.49 (0.21)	IDS-F > DCHD
Synchrony NP	0.22 (0.19)	0.30 (0.14)	0.30 (0.17)	IDS-F, IDS-M > DCHD
Synchrony RE	0.19 (0.20)	0.27 (0.22)	0.29 (0.22)	IDS-F, IDS-M > DCHD
Transitions NP	0.41 (0.11)	0.35 (0.10)	0.34 (0.09)	DCHD > IDS-F, IDS-M
Transitions RE	0.40 (0.11)	0.38 (0.10)	0.34 (0.10)	DCHD, IDS-M > IDS-F
Cell range NP	9.84 (3.05)	9.16 (2.52)	8.79 (1.99)	DCHD > IDS-F
Cell range RE	10.49 (3.83)	7.42 (2.04)	6.85 (1.96)	DCHD > IDS-F, IDS-M
Dispersion NP	0.74 (0.12)	0.75 (0.13)	0.75 (0.10)	*ns*
Dispersion RE	0.75 (0.14)	0.74 (0.12)	0.72 (0.12)	*ns*

Note. NP = normal play; RE = reunion.

The NP and RE episodes presumably place different demands on the dyad but because they are part of the same procedure separated by only two minutes, we conducted the analyses both ways (one factor analysis combining measures from the NP and RE episodes and separate factor analyses for the two episodes). Findings were analogous with regard to common and unique properties of dyadic interaction in the two episodes so findings from the combined factor analysis are reported.[1]

Principal axis factoring was used to extract factors. The squared multiple correlations were used for the initial commonality estimates. Because the selection of the number of factors in EFA is inherently subjective, an agreement between several techniques was used (Kim & Mueller, 1978). A combination of the Kaiser–Guttman rule (eigenvalues > 1.0), the scree test, and the theoretical interpretability of the resulting factors was used to determine the number of factors. For each of the data sets, all of the rules indicated that a five-factor solution was the most appropriate, accounting for 82.5% of the variance in the DCHD data set, 80.4% of the variance in the IDS-M data set, and 82.9% of the variance in the IDS father–infant data set. The eigenvalues for the first 5 factors for each data set are listed in Table 2. Because conceptually we expected the latent factors to be correlated, an oblique (Promax) rotation of the original solution was used to aid interpretation of the factors. Inter-factor correlations are presented in Table 3 (mother–infant data sets) and Table 4 (father–infant data set). Variables with factor loadings of greater than 0.30, which indicates that the factor accounts for greater than 10% of the

TABLE 2
Eigenvalues for the First Seven Factors Extracted from each Data Set

	Data set		
Factor number	*DCHD*	*IDS-M*	*IDS-F*
1	6.32	4.44	5.51
2	4.51	4.07	3.09
3	1.92	2.88	2.48
4	1.55	1.80	2.04
5	1.21	1.41	1.48
6	0.93	1.02	0.95
7	0.79	0.93	0.84

[1]Additional information about computation of variables and the factor analyses is available upon request from the corresponding author.

TABLE 3
Correlations Among Factors for Mother–Infant Data Sets (IDS-M Below the Diagonal; DCHD Above the Diagonal)

Factor	*1* *Infant positive NP*	*2* *Parent positive-dyadic asynchrony*	*3* *Infant positive RE*	*4* *Dyadic flexibility RE*	*5* *Dyadic flexibility NP*
1	–	−0.10	0.32	0.32	−0.12
2	0.00	–	−0.10	−0.38	−0.18
3	0.35	0.00	–	0.23	−0.10
4	0.17	−0.02	−0.01	–	0.27
5	0.01	−0.19	−0.09	0.31	–

Note. NP = normal play; RE = reunion.

TABLE 4
Correlations Among Factors for Father–Infant Data Set (IDS-F)

Factor	*1* *Infant positive dyadic flexibility NP*	*2* *Parent positive dyadic asynchrony*	*3* *Infant positive dyadic synchrony RE*	*4* *Dyadic flexibility RE*	*5* *Infant positive dyadic synchrony*
1	–				
2	−0.01	–			
3	0.20	0.18	–		
4	0.31	0.12	0.22	–	
5	0.24	0.03	0.25	0.11	–

Note. NP = normal play; RE = reunion.

variance, were used to interpret and label the factors (Tabachnick & Fidell, 2007). For clarity, only coefficients 0.30 and greater are included in Tables 5 and 6.

Overall there was consistency in the solutions across the DCHD and IDS-M data sets, suggesting that the identified factors were robust and replicable for mother–infant interaction across two independent samples. As seen in Table 5, five factors were replicated, with few variables loading on a factor in one data set and not in the other. Magnitudes of the factor loadings were similar across the two mother–infant data sets and the variables with the highest loadings on each factor were replicated across data sets. Results from the IDS-F data set indicated that the factors underlying father–infant interactions were only partially overlapping with those of mother–infant interactions, even though, in the IDS sample, mother–infant and father–infant interactions were observed within the same

TABLE 5
Factor Loadings of Obliquely (Promax) Rotated Factors of Mother–Infant Data Sets

	Infant positive NP		*Parent positive asynchrony*[a]		*Infant positive RE*[a]		*Dyadic flexibility RE*[a]		*Dyadic flexibility NP*	
Variables	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*
Infant gaze away RE	−0.40	−0.32								
Infant gaze away NP	−0.77	−0.59								
Latency peak positive NP	−0.62	−0.45								
Infant peak positive duration NP	0.49	0.50						−0.47	−0.39	
Infant peak positive rate NP	0.84	0.82								
Infant positive affect NP	0.83	0.90								
Parent positive affect NP	0.30	0.33	0.83	0.83						
Parent positive affect RE			0.85	0.79		0.33				
Parent peak positive duration NP			0.45	0.63					−0.39	
Parent peak positive duration RE			0.68	0.48						
Synchrony NP			−0.52	−0.54						
Matched affect NP		0.52	−0.79	−0.76						
Matched affect RE			−0.35	−0.38	0.70	0.72				
Infant negative affect RE					−0.88	−0.93				
Infant latency peak negative RE					0.68	0.82				
Infant latency peak positive NP	−0.40					−0.36		−0.40		
Infant peak positive duration RE		0.48			0.42					
Synchrony RE			−0.37		0.40			0.37		
Infant peak positive rate RE	0.30				0.50	0.59	0.32	0.39		
Flexibility: cell range RE							0.77	0.69		
Flexibility: dispersion RE							0.94	0.81		
Flexibility: transitions RE							0.85	0.64		
Flexibility: cell range NP	0.33		−0.38						0.56	0.78
Flexibility: transitions NP									0.63	0.76

Continued

Table 5 *(Continued)*

	Infant positive NP		*Parent positive asynchrony*[a]		*Infant positive RE*[a]		*Dyadic flexibility RE*[a]		*Dyadic flexibility NP*	
Variables	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*	*DCHD*	*IDS-M*
Latency peak negative NP									–0.48	–0.55
Flexibility: dispersion NP			–0.42						0.65	0.74
% Variance explained by factor[b]	28.4%	26.7%	31.6%	24.0%	21.9%	23.3%	25.4%	19.9%	17.4%	19.9%

Notes. NP = normal play; RE = reunion.
[a]Factors with superscripts are common to those that occurred in the father–infant data set with the same labels (see Table 6).
[b]% Variance explained by factor was calculated by dividing the eigenvalue of the obliquely rotated factor by the final communality estimate for the sample. Eigenvalues were calculated ignoring correlated factors, thus non-unique variance is included more than once, causing the sum of variance explained across all factors to be greater than 100%.

TABLE 6
Factor Loadings of Obliquely (Promax) Rotated Factors of Father–Infant Data Set

Variables	*Parent positive asynchrony*[a]	*Infant positive RE*[a]	*Dyadic flexibility RE*[a]	*Infant positive flexibility NP*	*Infant positive NP synchrony*
Infant gaze away RE			−0.34		
Infant gaze away NP				−0.59	
Latency peak positive NP				−0.54	
Infant peak positive duration NP					0.57
Infant peak positive rate NP				0.75	
Infant positive affect NP				0.47	0.51
Parent positive affect NP	0.78				
Parent positive affect RE	0.72	0.33			
Parent peak positive duration NP	0.60				0.30
Parent peak positive duration RE	0.62		−0.30		
Synchrony NP					0.56
Matched affect NP	−0.61				0.45
Matched affect RE	−0.32	0.66			0.35
Infant negative affect RE		−0.89			
Infant latency peak negative RE		0.76			
Infant latency peak positive NP		−0.57			
Infant peak positive duration RE		0.34			0.35
Synchrony RE		0.36			0.42
Infant peak positive rate RE		0.47	0.44		
Flexibility: cell range RE			0.81		
Flexibility: dispersion RE			0.84		
Flexibility: transitions RE			0.92		
Flexibility: cell range NP		−0.47		0.55	
Flexibility: transitions NP				0.81	−0.42
Infant latency peak negative NP					0.42

Continued

Table 6 *(Continued)*

Variables	*Parent positive asynchrony*[a]	*Infant positive RE*[a]	*Dyadic flexibility RE*[a]	*Infant positive flexibility NP*	*Infant positive NP synchrony*
Flexibility: dispersion NP				0.80	
% Variance explained by factor[b]	19.2%	26.7%	23.3%	27.4%	21.2%

Notes. NP = normal play; RE = reunion.
[a]Factors with superscripts are common to those that occurred in mother–infant data sets with the same labels (see Table 5). [b]% Variance explained by factor was calculated by dividing the eigenvalue of the obliquely rotated factor by the final communality estimate for the sample. Eigenvalues were calculated ignoring correlated factors, thus non-unique variance is included more than once, causing the sum of variance explained across all factors to be greater than 100%.

families. Three of the five factors were common to mother–infant and father–infant interactions, but two other factors were unique to father–infant interactions (Table 6).

Factor descriptions

Infant positive in NP

This factor emerged in mother–infant interactions only. Infants in dyads scoring high on this factor showed relatively higher levels of measures of positive affect and engagement in NP. Most variables loading on this factor were individual infant measures and specific to the NP episode (Table 5).

Parent positive-dyadic asynchrony & inflexibility

Variable loadings on this factor were similar across the three data sets. Parents in dyads scoring high on this factor showed higher levels of measures of positive affect and engagement and remained positive regardless of context and the dyads had lower levels of matched affect. In mother–infant interactions, dyads scoring high on this factor were also lower in dyadic synchrony and flexibility. This factor, unlike most others, was composed of both dyadic and individual measures, but individual measures of parents only, and measures that were not specific to context (Tables 5 and 6).

Infant positive in RE

Variable loadings for this factor were similar across the three data sets. Infants in dyads scoring high on this factor showed relatively less negativity and higher positive affect and engagement in the RE episode. Dyads showed higher levels of matched affect and, moderately in two of the data sets, higher dyadic synchrony. Most variables loading on this factor were individual infant measures and most were specific to RE. This factor was moderately correlated with the *Infant Positive in NP* factor, suggesting that positive affect is both stable and changes as a function of contextual demands (Tables 5 and 6).

Dyadic flexibility in RE

Variable loadings for this factor were similar across the three data sets. Dyads scoring high on this factor showed greater flexibility in RE (Tables 5 and 6).

Dyadic flexibility in NP

This factor emerged in mother–infant interactions only. Dyads scoring high on this factor showed flexibility in NP. The *Dyadic Flexibility in NP* and *Dyadic Flexibility in RE* factors were modestly correlated, suggesting that dyadic flexibility may be characteristic of dyads but also sensitive to contextual demands (Table 5).

Infant positive-dyadic flexibility in NP

This factor emerged only in father–infant interaction. Infants in dyads scoring high on this factor showed relatively greater positive affect and engagement and dyads showed greater flexibility in NP (Table 6).

Infant positive NP-dyadic synchrony

This factor emerged only in father–infant interaction. Infants in dyads scoring high on this factor showed relatively greater positive affect and engagement in NP. Dyads showed relatively higher dyadic synchrony and matched affect across contexts. Dyads also showed lower levels of one measure of flexibility in NP. This factor showed a low correlation with *Infant Positive-Dyadic Flexibility in NP*, suggesting that in father–infant interaction, flexibility and synchrony may be independent processes (Table 6).

DISCUSSION

Researchers have used a variety of measures to assess the quality of dyadic interaction. Methodological issues in studying dyadic interaction include how individual partners' behaviors are related to dyadic measures, the conflation of measures of valence and measures of process, and a need to better understand the role of context. In addition, little work has examined father–infant interactions. To advance conceptually informed measurement of dyadic interaction, this study examined factor structure of individual parents' and infants' measures and dyadic measures from face-to-face interactions in two samples of 6-month-old infants and their parents.

Overall, findings emphasized the need to measure multiple aspects of dyadic interaction to adequately and accurately assess the construct, including measures of individual parents' and infants' behaviors, dyadic measures, and measures of valence and of process. As expected, consistent with dyadic expansion theory (Tronick, 2005), which proposes that dyadic interaction is greater than the sum of its parts, dyadic measures and individual measures generally loaded on separate factors, though this was the case to a lesser degree in father–infant interaction. Although expected theoretically, the current findings contribute to the methodological literature by validating empirically that individual behavior, even when observed in a dyadic context, and dyadic measures, although computed from individual behavior, provide unique information.

Contrary to expectations that parent and infant individual behaviors would load on the same factors, based on theories of bi-directional influence, parents' behaviors across contexts, for the most part, loaded on a single factor, and infants' behaviors contributed to multiple factors and tended to load on separate factors as a function of context. This suggests that infants may contribute variability to dyadic interaction while parents contribute stability and consistency.

The factor specific to parents' behaviors was found in mother–infant and father–infant interactions and was characterized by high levels of parents' positive affect and engagement across contexts and low dyadic synchrony and matched affect. This finding highlights the need to incorporate measures of both affective valence and temporal process when assessing the quality of dyadic interaction, and more broadly, highlights the importance of not interpreting any of the measures in isolation as indicating a "good" or "effective" dyadic interaction. For example, although high levels of parents' positivity are typically considered to be indicative of a sensitive parent, the relation with low dyadic synchrony and matched affect could indicate lower behavioral responsiveness to infants' cues. Similarly, although greater synchrony or greater matched affect are sometimes thought to indicate more responsiveness in the dyad, if coupled with higher levels of negative affect could indicate a dyadic interaction characterized by frequent and contingent expressions of negative emotion.

Overall, there were context-general and context-specific factors, with variables measured in the NP and RE episodes often loading on separate factors but showing moderate correlation. This suggests that dyadic interaction can be conceptualized as having both trait-like and context-specific processes. That parents' behaviors across contexts loaded primarily on one factor while infants' behaviors in specific contexts loaded on separate factors suggests that change and context-specificity may be driven by infants' affective behaviors to a greater degree than parents'. This is consistent with research finding that by 6 months of age infants become more active in structuring face-to-face interactions with their mothers (Cohn & Tronick, 1988) and with theoretical conceptualizations of parents as providing a predictable structure and organization to the interaction that helps to support the infants' rapidly changing development (e.g., Gianino & Tronick, 1988).

The current study contributed to the body of research on dyadic interaction by examining measures of father–infant interaction. There were some common factors found between mother–infant and father–infant interactions, and some differences. Although the exploratory nature of the current work does not allow us to make strong interpretations about similarities and differences between the structures of mother–infant and father–infant interactions, the findings provide direction for future research to examine these differences. With that caveat, the factor structure of dyadic interaction was more similar between mother–infant dyads from two independent samples than it was between mother–infant and father–infant interactions within the same families. The factors that were unique to father–infant interaction were distinguished from the two factors unique to mother–infant interaction by dyadic measures. In mother–infant interaction, infant positive affect in both the NP and the RE episodes loaded on different factors from dyadic synchrony in those episodes. Father–infant interaction, although also context specific to the NP and RE episodes, linked infant positive affect and dyadic synchrony, suggesting that infants' may play a greater role in the organization of dyadic interactions with their fathers than with their mothers.

The current work is consistent with prior research that has found differences between mother–infant and father–infant interaction (e.g., Braungart-Rieker et al., 1998; Feldman, 2003; Forbes, et al., 2004) but extends that work to suggest that there may be more similarities than differences in the ways mothers and fathers interact with their infants. Where differences occur, it is possible that mothers take a more active role in structuring interactions than do fathers, at least during infancy, which may account for the greater unpredictability found in father–infant interaction (e.g., Braungart-Rieker et al., 1998). Together with research that has found fewer externalizing behaviors later in development when fathers were less flexible and mothers were more flexible during interactions with their 3-year-olds, there may be optimal levels of consistency and predictability, with mothers tending in the direction of too much and fathers in the direction of too little. This suggestion is speculative, however, and should be tested in future research.

The current research also extended prior research by examining dyadic flexibility, a construct relatively new to infancy research (Hollenstein et al., 2004), in relation to other dyadic measures. Results suggested that measures of flexibility may index aspects of dyadic interaction that are not captured by measures of another, more widely used measure, synchrony, particularly for father–infant interaction where synchrony and flexibility were negatively related. In mother–infant interaction, measures of dyadic flexibility and individual parent and infant measures did not load on the same factors. In contrast, in father–infant interaction, flexibility in the NP and several measures of infant positive affect and engagement loaded on the same factor, suggesting that flexibility in father –infant interaction is a function of infants' behaviors to a greater degree than in mother–infant interactions. Measures of flexibility describe the degree to which dyads move among different affective states and the rate at which they shift states (Hollenstein et al., 2004). Therefore, flexibility may be a more informative measure than synchrony of the process of matching and mismatching affective states, the important process of interactive repair that is thought to be fundamental to mutual regulation (Tronick, 2005).

These findings may be particularly applicable to researchers studying parent–infant interaction using the FFSFP, which was developed to assess infants' responses to a perturbation in dyadic interaction within the framework of mutual regulation. Multiple measures that capture information about both valence and process and newer measures, such as flexibility, may be needed to adequately assess the degree and quality of mutual regulation. In addition, findings suggest that when assessing parenting behavior, aggregating across the interactive episodes would be appropriate, whereas measures of infant behavior appear to be more sensitive to the contextual demands of each episode.

Limitations

One caveat is that the variables used in the factor analyses were selected to represent theoretical qualities of dyadic regulation and included a range of individual and dyadic measures that captured temporal and valence dimensions. All measures had been used in previous research and found to be related to dyadic regulation and its correlates. Other variables that were not studied, such as global ratings of individuals or of dyads, may also be appropriate to assess dyadic interaction. In addition, the way in which some variables were computed may have affected their factor loadings. For example, two factors were characterized predominantly by measures of flexibility that were unique in being computed using GridWare software (Lamey et al., 2004). However, measures of flexibility in NP and RE loaded on separate factors, suggesting the factors specific to flexibility were not exclusively due to methodology. EFA does not provide as strong evidence for similarities and differences between the structures of mother–infant and father–infant interactions as would confirmatory factor analysis (CFA). Because we began with a set of measures that were correlated and we had no a priori hypotheses about the number of factors or specific patterns of relations among the measures, EFA appeared to be the better choice. Future research using CFA could extend the current research by generating specific variables to be used to test mother–infant and father–infant differences and testing factor structure equality by constraining the structures to be equal across groups.

Although the findings of this study extend knowledge regarding the measurement of dyadic interaction, additional research is needed to clarify the way in which these qualities and processes are related to children's development. The current findings emphasize the need to move beyond simplistic interpretations of various measures and suggest that dyadic interaction may be better characterized by a pattern of measures, none of which alone is sufficient to characterize the rich complexity of dyadic interaction.

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