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Six-Week Postpartum Maternal Self-Criticism and Dependency and 4-Month Mother–Infant Self- and Interactive Contingencies

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Associations of 6-week postpartum maternal self-criticism and dependency with 4-month mother–infant self- and interactive contingencies during face-to-face play were investigated in 126 dyads. Infant and mother face, gaze, touch, and vocal quality were coded second by second from split-screen videotape. Self- and interactive contingencies were defined as auto- and lagged cross-correlation, respectively, using multilevel time-series models. Statistical significance was defined as $p < .05$. Regarding self-contingency, (a) more self-critical mothers showed primarily lowered self-contingency, whereas their infants showed both lowered and heightened, and (b) infants of more dependent mothers showed primarily lowered self-contingency, whereas findings were absent in mothers. Regarding interactive contingency, (a) more self-critical mothers showed lowered attention and emotion contingencies but heightened contingent touch coordination with infant touch, and (b) more dependent mothers and their infants showed heightened facial/vocal interactive contingencies. Thus, maternal self-criticism and dependency have different effects on mother–infant communication.

Keywords: mother–infant contingency, maternal self-criticism, maternal dependency, mother–child relations

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We examined associations between 6-week postpartum maternal dependency and self-criticism (Blatt, D'Afflitti, & Quinlan, 1979) and 4-month mother–infant self- and interactive contingencies during face-to-face play. Despite extensive investigation of maternal depressive symptoms, other forms of maternal distress, such as a personality-based rather than a symptom-based approach to depressive vulnerability, remain understudied. We investigated whether maternal self-criticism and dependency are associated with different patterns of mother–infant communication.

We assessed maternal personality with the Depressive Experiences Questionnaire (DEQ; Blatt & Zuroff, 1992). This reliable, well-validated self-report instrument distinguishes two profiles: (a) *self-criticism*, excessive concern with self-worth and achievement, and (b) *dependency*, excessive concern with maintenance of interpersonal relatedness. These two profiles are distinct in triggering events, nature of depressive experience, and interpersonal behavior (Alden & Bieling, 1996; Coyne & Whiffen, 1995). Despite extensive use in the adult literature, this approach is curiously absent in the infant literature. Parenting is affected by excessive concerns with self-definition and relatedness (Priel & Besser, 2000; Thompson & Zuroff, 1998), but only a few researchers have used these measures with mothers and infants (Kaminer, 1999; Kaminer, Beebe, Jaffe, Kelly, & Marquette, 2007; Kushnick, 2002; Vliegen & Luyten, 2006).

Self-critical individuals, preoccupied with self-definition, are vulnerable to depressive experience with achievement failures.

They exhibit excessive personal demands for accomplishment and control, and feel inferior when depressed. In conflict resolution studies, they show a hostile and critical style. They are less likely to seek emotional support (Blatt, 2004). Dependent individuals, preoccupied with relatedness, are vulnerable to depressive experience with ruptures in important relationships and avoid offending others for fear of losing support. Less psychologically reflective, they express dysphoria in somatic complaints. When separated from significant others, they experience distress; when regulating negative affect, they are less likely to spend time alone (Blatt, Hart, Quinlan, Leadbeater, & Auerbach, 1992; Fichman, Koestner, Zuroff, & Gordon, 1999). This personality approach can reveal different meanings that a transaction might hold for a mother. For example, moments of infant gaze aversion (an adaptive means of decreasing arousal) might be misinterpreted by dependent mothers as loss of the infant's interest but by self-critical mothers as a failure in mothering (Kaminer et al., 2007).

Dependency and self-criticism define two broad personality types that differ in forms of defense (avoidant vs. counteractive), attachment styles (preoccupied vs. avoidant/dismissive), modes of cognition (concerns about people vs. objects; synthesis vs. critical analysis), and styles of affect regulation (labile/expressive vs. overcontrolled/distant; Blatt, 2004). Moreover, symptom-based depression measures, such as the Beck Depression Inventory (BDI; Beck, Steer, & Garbin, 1988) and the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977), assess primarily self-critical dimensions of depression, whereas the dependent dimension, overrepresented in females, is less studied (Blatt, 2004). Thus, we expected that dependent versus self-critical personality dimensions would show differential effects on mother–infant interactions, facilitating a fuller exploration of early communication.[1]

Self- and Interactive Contingencies

Our focus is the *dyadic temporal process*, contingency analyses (by multilevel time-series modeling) of the moment-to-moment sequence of behaviors. We evaluated two dimensions of contingencies within the dyadic encounter: (a) *self-contingency,* within each individual's behavioral stream, and (b) *interactive contingency,* between the two partners' streams.

Infants have remarkable capacities to detect regularities in events, to perceive contingencies, and to predict when events will occur. They perceive temporal relations between environmental events and between their own behaviors and environmental consequences. Infants are sensitive to ways that their behaviors are contingently responded to, and they differentiate the relative degree of partner contingent coordination (Bigelow, 1998; DeCasper & Carstens, 1980; Hains & Muir, 1996; Haith, Hazan, & Goodman, 1988; Millar, 1988; Murray & Travarthen, 1985; Tarabulsy, Tessier, & Kappas, 1996; Watson, 1985).

Despite many approaches to the study of social contingencies, time-series approaches have emerged as dominant in the last two decades (Cohn & Tronick, 1988; Gottman, 1981; Sackett, Holm, Crowley, & Henkins, 1979). Time-series techniques partial out the variance in an individual's behavior due to self-contingency (autocorrelation) from that due to contingent coordination with the partner (crosscorrelation). These methods usually control for autocorrelation rather than use it as a variable in its own right. Although our method of multilevel time-series analysis (Chen & Cohen, 2006; Cohen, Chen, Hamgiami, Gordon, & McArdle, 2000; Singer & Willett, 2003) introduces refinements, it is similar to that of many other researchers (Cohn & Tronick, 1988; Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001).

We differ, however, in our emphasis on autocorrelation, which others have ignored (Stern, 1971) or removed statistically (Cohn & Tronick, 1988; Jaffe et al., 2001). We treat it as a variable in its own right, an approach with precedent (Badalamenti & Langs, 1990; Crown et al., 1996; Holtz, 2004; Thomas & Malone, 1979; Warner, 1992), which has yielded robust results in our prior work. For example, depressed mothers and their infants both showed lowered autocorrelation during 4-month play (Beebe et al., in press). When one's ongoing behavioral stream is less predictable, one is less able to anticipate one's own next move. Furthermore, infant 4-month self-contingency measures predicted 12-month attachment (Beebe, Jaffe, et al., 2007).

Distress Biases the Communication System Toward Both Heightened and Lowered Contingencies

The role of interpersonal contingencies in mother–infant face-to-face communication has been unclear (Cohn & Elmore, 1988; Jaffe et al., 2001; Keller, Lohaus, Volker, Cappenberg, & Chasiotis, 1999; Tarabulsy et al., 1996). Studies have been inconsistent as to whether distressed dyads show altered interactive contingencies; studies have differed by statistical approach, infant age, severity of maternal distress, and socioeconomic status (Cohn & Tronick, 1989; Cohn, Campbell, Matias, & Hopkins, 1990; Field, Healy, Goldstein, & Guthertz, 1990). Competing hypotheses in the literature regarding interactive contingency suggest that (a) high contingency is optimal for communication (Chapple, 1970), (b) high contingency indexes communicative stress (Gottman, 1981), or (c) midrange contingency is optimal (Cohn & Ellmore, 1988; Jaffe et al., 2001; Warner, Malloy, Schneider, Knoth, & Wilder, 1987). Most infant literature considers higher contingency more optimal (Dunham & Dunham, 1994; Tarabulsy et al., 1996; Van Egeren, Barratt, & Roach, 2001).

Jaffe et al. (2001) found that midrange interactive contingencies of 4-month mother–infant and stranger–infant vocal rhythms predicted secure attachment, whereas both low and high predicted insecure. High contingency was interpreted as "vigilance," a dyadic effort to create more predictability in the interaction; low contingency was interpreted as inhibition or withdrawal. Other research has converged on such a model, in which distress biases the system toward both heightened interactive contingency (in some measures) and lowered (in others; Beebe, Hane, et al., 2007; Beebe, Jaffe, et al., 2007; Beebe et al., in press; Belsky, Rovine, & Taylor, 1984; Hane, Feldstein, & Dernetz, 2003; Holtz, 2004; Lewis & Feiring, 1989; Leyendecker, Lamb, Fracasso, Scholmerich, & Larson, 1997; Malatesta, Culver, Rich, & Shepard, 1989; Roe, Roe, Drivas, & Bronstein, 1990).

[1] The rationale for using the DEQ measures in relation to mother–infant interaction, and much of the argument to this point in the article, was first developed by Kaminer et al. (2007).

The Problem of Low Scores in Self-Report Scales

Self-report scales constitute the central measurement of maternal distress in child development research. These scales are vulnerable to "denial" of distress (Shedler, Mayman, & Manis, 1993), so that low scores may be difficult to interpret. Using coronary reactivity, Shedler et al. (1993) showed that some subjects with low self-report depression had lower coronary reactivity; but for subjects clinically judged "distressed," lower depression scores were correlated with the highest coronary reactivity. Pickens and Field (1993) showed that infants of low-scoring mothers (BDI) had more negative facial expressions, whereas Tronick, Beeghly, Weinberg, and Olson (1997) argued that low scores (CES-D) represented "postpartum exuberance." Some mothers at the low end may indeed be distress free, whereas others may deny distress. Shedler et al. (1993) solved this problem with an independent physiological measure of distress.

Mothers volunteering for a study of infant social development, such as ours, may be motivated to downplay distress. We explored low scores using nonlinear analyses of DEQ self-criticism and dependency in relation to contingency. If low and high poles of DEQ are associated with similar alterations in contingency, the low DEQ pole may be problematic. However, without an independent distress measure, we remain cautious: Some subjects at the low DEQ pole may indeed be distress free.

Approach of the Study

Mother–infant face-to-face communication generates multiple simultaneous emotional signals, typically congruent, such as patterns of gaze, facial expression, vocal quality, and touch. Whereas composite multimodal measures such as "monadic phases" (Tronick, 1989) or facial-visual "engagement" (Beebe & Gerstman, 1980) have often been used, composite measures neglect the unique contributions of different modalities. Moreover, different communication modalities can convey *discordant* information, difficult to integrate into a coherent percept (Shackman & Pollak, 2005). Only examination of separate modalities can identify such discordant communication: our approach (see also Bahrick, Hernandez-Reif, & Flom, 2005; Keller et al., 1999; Van Egeren et al., 2001; Weinberg & Tronick, 1994; Yale, Messinger, Cobo-Lewis, & Delgado, 2003). In our prior work, both modality and degree of contingency were sensitive to maternal depressive symptoms (CES-D; Beebe et al., in press). For example, high CES-D mothers and their infants lowered their coordination with the partner's gaze but heightened their coordination with the partner's facial affect: a discordance in attention versus affect coordination.

The current study analyzed behavioral scales of (a) attention (gaze on/off the partner's face), (b) emotion (positivity of facial and vocal quality), (c) maternal touch in relation to infant vocal quality and touch, and (d) an intrapersonal pattern of infant vocal quality in relation to infant touch. Gaze and face are central modalities of face-to-face exchange (Kaye & Fogel, 1980; Tronick, 1989). Vocal quality is an important form of emotional communication, particularly vocal distress (Fernald, 1993). Infant touch is important for infant self-soothing (Tronick, 1989; Weinberg & Tronick, 1994). Affectionate to intrusive patterns of maternal touch are a central but less examined modality (Field, 1995; Moreno, Posada, & Goldyn, 2006; Stepakoff, Beebe, & Jaffe, 2000; Stack, 2001). We did not analyze maternal vocal quality (our vocal rhythm measure [Jaffe et al., 2001] will be used in a separate report).

Five mother–infant interpersonal "modality pairings" were examined: (a) infant gaze–mother gaze, (b) infant face–mother face, (c) infant vocal quality–mother face, (d) infant vocal quality–mother touch, and (e) infant touch–mother touch. Our criterion was the same modality for both partners where possible (pairings 1, 2, and 5). We examined infant vocal quality as a second way of exploring the infant's emotional response to the mother's face (see Hsu & Fogel, 2003). We explored maternal touch in relation to infant vocal quality as well as infant touch, reasoning that infants may respond to more intrusive forms of maternal touch with vocal distress or with increased self-touch efforts (see Van Egeren et al. [2001], who found robust bi-lateral contingencies between mother touch and infant vocalization).

We explored a sixth infant intrapersonal pairing: touch–vocal quality. Following Tronick's (1989) view that infant self-touch has a self-comforting function, inhibiting negative infant affect, we tested whether more infant touch predicts less infant vocal distress, whether infant vocal distress affects infant touch, and whether maternal self-criticism or dependency affect these patterns.

As a function of 6-week maternal self-criticism and dependency, we thus investigate (a) which partner shows 4-month altered contingency, mother or infant; (b) the type of contingency that is altered, self- or interactive; (c) whether contingency is increased or decreased; and (d) the modality of contingency that is altered.

Hypotheses

1. Building on our prior findings in which insecure attachment was associated with both heightened and lowered values of interactive contingency (Jaffe et al., 2001), we hypothesize that distress (maternal self-criticism or dependency) biases the mother–infant communication system toward both heightened and lowered contingency. As a function of partner (mother/infant) and communication modality (attention, emotion, touch), we hypothesize that with higher (vs. lower) maternal self-criticism and dependency, values of self- and interactive contingency will be both heightened (in some modalities) and lowered (in others). We also explore whether higher (vs. lower) self-criticism and dependency will be associated with differences in means of behavioral scales of attention, emotion, and touch.

2. Following Blatt (2004) and colleagues, we conjecture that self-criticism and dependency will differ in patterns of contingency. Without prior infant literature to generate specific hypotheses, we conjecture that maternal self-criticism will be associated with heightened maternal self-contingency, consistent with the emphasis on self-definition, together with lowered maternal emotional interactive contingency, consistent with the avoidant, dismissive emotional style of this configuration. We conjecture that maternal dependency will be associated with heightened maternal emotional interactive contingency, the hallmark of this personality configuration, together with lowered maternal emotional self-contingency, exacerbating emotional vigilance.

3. Because low scores are ambiguous in self-report scales, we use nonlinear analyses to explore whether contingency patterns in which mothers' DEQ scores move toward the low pole look similar to the patterns in which mothers' DEQ scores move toward the high pole.

Method

Participants

Recruitment. Within 24 hours of delivering a healthy full-term, singleton infant without major complications, 152 mothers

were recruited from Columbia University Medical Center for a study of infant social development involving a 4-month lab visit for videotaping (1992–1998).[2] Subjects were primiparous women, 18 years or older, married (or living with partner), with home telephone. At 6 weeks, 152 mothers were contacted by telephone and given the DEQ (Blatt et al., 1979). At 4 months, 132 mothers and infants were videotaped in the lab. Of these 132, 126 had completed the DEQ at 6 weeks. No differences were found in ethnicity, education, or infant gender between the 126 participants and the 152 recruited.

Demographic description. Mothers had a mean age of 29 years ($SD = 6.5$, range 18–45); were 53.0% White, 28.0% Hispanic, 17.5% Black, 1.5% Asian; and were well-educated (3.8% without high school diploma, 8.3% without college, 28.8% with some college, 59.1% with college degree or more). Subjects were a low-risk community group. Of the 126 infants, 54 were female.

Procedure

Scheduling of 4-month videotaping took into account infant eating/sleeping patterns. Mothers (seated opposite infants in an infant seat on a table) were instructed to play with their infants as they would at home, but without toys, for approximately 10 min (necessary to obtain vocal rhythm data for a separate report). A special effects generator created a split-screen view from input of two synchronized cameras focused on mother and infant. After videotaping, mothers again filled out the DEQ.

Measurement of Maternal Self-Criticism and Dependency (DEQ)

The DEQ is a 66-item, 7-point self-report scale tapping vulnerability to depressive experiences (rather than symptoms; Blatt et al., 1979). Self-criticism and dependency factor loadings for a female sample were used. The mean score for each factor is 0.0 with standard deviation of ± 1.00. Test–retest reliabilities for dependency range from .89 (5 weeks) to .81 (13 weeks) and for self-criticism from .83 (5 weeks) to .75 (13 weeks; Zuroff, Moskowitz, Wielgus, Powers, & Franko, 1983). Internal consistency (coefficient alpha) is .81 for dependency, .80 for self-criticism (Blatt, Quinlan, Chevron, McDonald, & Zuroff, 1982). Dependency and self-criticism are correlated with the BDI in clinical populations and with depressive affect in college populations (Zuroff & Mongrain, 1987). We chose 6-week[3] rather than 4-month DEQ to see whether maternal vulnerability at this early stage is associated with interactions 2.5 months later.

Behavioral Coding

The first 2.5 uninterrupted continuous play minutes of videotaped mother–infant interaction were coded on a 1-s time base (see Cohn & Tronick, 1989; Field et al., 1990) by coders blind to DEQ status, using Tronick and Weinberg (1990) timing rules. Behavioral codes were used to create ordinalized scales for data analysis (required by time-series techniques). The anchors of these ordinalized scales were as follows: *mother face*—mock surprise to negative face; *infant face*—high positive to negative; *gaze*—on-off partner's face; *infant vocal quality*—positive to angry protest/cry; *infant touch*—2+, 1, or none of touch behaviors; and *mother touch*[4]— "affectionate" to "high intensity/intrusive." Reliability estimates of ordinalized scales were assessed in 30 randomly selected dyads (tested in 3 waves to prevent coder "drift"). The mean Cohen's kappa on infant and mother ordinalized scales was .80 (range per scale was .68–.90). Definitions of the behavioral codes for the ordinalized scales can be found on our Web site, http://nyspi.org/Communication_Sciences/index.html.

Using the ordinalized scales, the following five mother–infant modality pairings and a sixth intrapersonal infant pairing were generated for data analysis: (a) infant gaze – mother gaze, (b) infant face – mother face, (c) infant vocal quality – mother face, (d) infant vocal quality – mother touch, (e) infant touch – mother touch, and (f) infant touch – infant vocal quality.

Data Analysis

Modeling the complexity of real-time interactions remains difficult. Whereas traditional time-series approaches have been considered state of the art, the multilevel time-series models used in this study have many advantages.[5] The SAS PROC MIXED program (Littell, Miliken, Stoup, & Wolfinger, 1996; McArdle & Bell, 2000; Singer, 1998) was used to estimate "random" (indi-

[2] This data set is entirely different from that reported in Jaffe et al. (2001).

[3] Any missing values for 6-week DEQ were estimated from 8-week DEQ values, which were available on a small subset assessed at 8 rather than 6 weeks, or from 4-month DEQ values corrected by the 6-week group mean, using regression analyses to impute missing scores.

[4] Mother touch reliability was assessed on individual touch behaviors; the ordinalized touch scale was created through an algorithm.

[5] Multilevel models are designed to address patterns over time (here the course of behavior second by second). To analyze interactive contingency, traditional time-series techniques first create two separate estimates per dyad of the magnitude of the effect of each partner's prior behavior on the other, controlling for autocorrelation. These estimates are then entered into regression equations to relate them to some other variable (e.g., maternal dependency); the error of the individual scores is lost. These ordinary least squares (OLS) estimates for each partner make the invalid assumption that the model predictors are fixed: that they represent investigator-selected (e.g., maternal) behaviors. This assumption ignores a source of error when the predictor (such as, which mothers score high on dependency) is not manipulated by the investigator. This source of error is taken into account in the multilevel time-series models, producing more accurate estimates. Multilevel models (Singer & Willett, 2003) have more power, take into account error structures, and estimate individual effects with empirical Bayesian (maximum likelihood) techniques (rather than OLS), which take into account prior distributions. Because the prior probability of error is greatest for the extreme parameters, this method tends to pull in such extremes. Advantages of this approach include the following: (a) Multiple time-series (in our case, self- and interactive contingency) can be modeled simultaneously, (b) An average effect of key parameters (e.g., infant behavior contingent on mother behavior) is estimated for the group and allows the investigator to ask how that group mean changes in the context of other factors such as maternal dependency, (c) Control variables and their conditional effects can be included as necessary, (d) Potential nonlinear relations can be examined in the same analyses, and (e) More appropriate statistical model assumptions are made.

vidual differences) and "fixed"[6] (common model) effects on patterns of self- and interactive behavior over 150 s. The models examined six modality pairings, including one, mother gaze–infant gaze (on/off gaze), in which the dependent variable is dichotomous and therefore analyzed by SAS GLIMMIX (Cohen et al., 2000; Goldstein, Healy, & Rasbash, 1994; Littell et al., 1996). For details of statistical models, see Chen and Cohen (2006). These analyses used all 150 s coded from videotape for each individual. In these models, repeated observations on individuals are the basic random data, just as in cross-sectional data single individual variables are the basic units of analyses. Fixed effects, in contrast, indicate average effects over the full sample so that it is possible to estimate the extent to which a single overall model accounts for the individual differences reflected in the random model.

Preliminary analyses estimated the number of seconds over which lagged effects were significant and their magnitude for the pairs as a whole (fixed model estimates). For each dependent variable, measures of prior self or partner behavior, "lagged variables," were computed as a weighted average of the recent prior seconds based on these analyses. Typically the prior 3 s sufficed to account for these lagged effects on the subsequent behavior.[7] The estimated coefficient for the effects of these lagged variables upon current behavior over the subsequent 147 s of interaction indicates the level of self- or interactive contingency: the larger the coefficient, the stronger the contingency. Each subsequent analysis included both sources of contingency, thus estimated coefficients of one form of contingency control for the other.

Tests of hypotheses used fixed rather than random effects. In preparation for tests of DEQ, a "basic model" of fixed (average) effects was produced for each behavioral dependent variable. The modeling process for predicting the time-varying behavioral variable in question (e.g., mother face) considered all demographic variables, effects of lagged variables as described above, and all possible two-way interactions between control variables and self- and interactive contingency. Effects of lagged variables (of self and partner behavior) on current behavior represent the average self- and interactive contingency across the subjects. Therefore, when testing the effects of DEQ, any differences in the magnitude of these estimated coefficients in the fixed effects model reflect influences of DEQ on self- and interactive contingency. Because our goal was an examination of the effects of DEQ on self- and interactive contingency, we have posted on our Web site, http://nyspi.org/Communication_Sciences/index.html, the basic model tables of self- and interactive contingency (three for each of the six modality pairings, a total of 18 tables) and computation. Prior basic across-group analyses showed positive signs for self- and interactive contingency (Beebe et al., 2006).

Variables in the "basic" multilevel model were added in the following steps after the intercept of the dependent variable: (a) self- and partner lagged variables, (b) demographic variables, (c) conditional effects between demographic variables, and (d) conditional effects of demographic variables with lagged self and lagged partner behavior.

Following each basic model, a conditional model examined the effect of maternal DEQ self-criticism and dependency on each ordinalized behavioral scale and statistical interactions of DEQ with self- and interactive contingency. The linear and quadratic conditional effects of DEQ upon self- and interactive contingency were included in the same set of equations; linear and quadratic components each controlled for the other. Only those demographic variables from the basic models that were also associated with DEQ could possibly confound these effects. Gender and DEQ self-critical yielded the only significant association (see Results section). Therefore, infant gender was included in the DEQ self-critical models; all other demographic variables were dropped from further consideration. For the predicted value of mother behavior, the fixed effects equation for testing linear and nonlinear effects of DEQ self-critical (S-C) was

$$M = M_{lagged} + I_{lagged} + S\text{-}C + S\text{-}C^2 + \text{infant gender} + M_{lagged}*\text{gender} + I_{lagged}*\text{gender} + M_{lagged}*S\text{-}C + M_{lagged}*S\text{-}C^2 + I_{lagged}*S\text{-}C + I_{lagged}*S\text{-}C^2$$

where M_{lagged} represents a weighted mean of mother's lagged behavior, I_{lagged} represents a weighted mean of infant's lagged behavior, S-C represents DEQ-S (self-criticism), and $S\text{-}C^2$ represents DEQ-S squared. Coefficients in the fixed effects model for M_{lagged} and I_{lagged} predicting mother behavior represent mother self- and mother interactive contingency, respectively (see Chen & Cohen, 2006). An identical model, but without gender as a covariate, was run for DEQ dependency. Each model included a chi-square test of improvement of fit to the data. DEQ was used as a continuous variable; scales were centered by their means. Standardized regression coefficients are presented in all tables. Type I error was set at $p < .05$ for each model of the six modality pairings; all tests were two-tailed. With 126 dyads $\times$ 150 s = 18,900 s per partner per communication modality, we had ample power to detect effects.

Linear components evaluated the conditional effects of higher (vs. lower) DEQ scores on self- and interactive contingency; results were interpreted as characterizing higher DEQ scores.

[6] A "random effect" is the term used for identifying the differences in a variable (function, or association) among the study subjects. These always include variation in the mean of the dependent variable across observations, and variation in the variance of the dependent variable across observations; they usually include variation in the linear change in the dependent variable over time, and in our case it includes between-dyad variation in the auto-regressive effect. A "fixed effect" is the average association across study units (in our case, dyads), just as it would be in an ordinary regression analysis. These average effects will account for some fraction of the random effects, just as in an ordinary regression analysis predictors account for some fraction of the variance in the dependent variable.

[7] Preliminary analyses estimated the number of seconds over which lagged effects were statistically significant. For each dependent variable, measures of prior self or partner behavior, termed "lagged variables," were computed as a weighted average of the recent prior seconds, based on these analyses. Typically the prior 3 s sufficed to account for these lagged effects on the subsequent behavior. Across the modality pairings studied, mother was significant at 2–3 lags (2–3 s) for both self- and interactive contingency; evaluation of longer lags yielded nonsignificant results. Significant infant lags varied: for self-contingency, 2 lags (touch), 3 (face, gaze), and 4 (vocal quality); for interactive contingency, 6 lags (mother gaze $\rightarrow$ infant gaze), 5 (mother face $\rightarrow$ infant face), and 3 (mother face $\rightarrow$ infant vocal quality). Although some of the above modality pairings showed lags longer than 3 s, the amount of variance accounted for was very small for lags longer than 3 s. Note that in the analyses, no more than 3 lags were used in any weighted mean lag, to maintain a consistent sample size.

Nonlinear components evaluated quadratic conditional effects of DEQ; results were interpreted as characterizing movement toward the high and low poles, compared with dyads where mothers scored midrange in DEQ. Where nonlinear analyses were significant, movement toward both high and low poles of DEQ scores were associated with similar alterations in self- and interactive contingency (similar in direction but not necessarily in absolute amount). When both linear and nonlinear analyses were significant but yielded opposite signs of effects, findings were graphed and interpreted case by case.

Our interpretations occurred in two phases. Consistent with prior literature, the first phase evaluated findings associated with higher DEQ scores. Here we interpreted the linear as well as the higher portion of the nonlinear effects of DEQ (right-hand side of graphed effects) on self- and interactive contingency. The second phase examined nonlinear findings to evaluate whether movement away from the center toward the high and low poles of DEQ scores was associated with similar increases (or decreases) in self- and interactive contingency.

Results

We first present descriptive information about the DEQ scales, followed by univariate tests of associations between 6-week maternal DEQ self-criticism and dependency and means of 4-month ordinalized behavioral scales (face, gaze, touch, and vocal quality). Effects of self-criticism and dependency on 4-month self- and interactive contingency are then addressed. We first describe the pictures of self-criticism and dependency associated with higher DEQ scores, consistent with the literature, addressing contingency findings associated with higher DEQ, whether linear or nonlinear. We then return to the nonlinear equations to evaluate whether contingency findings of low-scoring DEQ dyads look similar to those of high-scoring dyads, interpreting nonlinear effects for both low and high poles of DEQ.

Description of DEQ Scales

The mean value (and *SD*) of 6-week self-criticism is −0.73 (0.96); of 4-month self-criticism, −0.80 (1.0); of 6-week dependency, −0.91 (0.71); and of 4-month dependency, −0.88 (0.80). Tables 1 and 2 present correlations of self-criticism, dependency, and CES-D. At 6 weeks, self-criticism and dependency share about 5% of the variance; self-criticism and CES-D 25%; and dependency and CES-D 3.6%. Histograms of 6-week self-criticism and dependency show normal distributions; neither is particularly skewed (skewness for self-criticism = .325 [*SE* = 0.216], skewness for dependency = −.482 [*SE* =0.216]), and representation at the high end is adequate for our conclusions.

Table 1
Correlations of DEQ and CES-D Scales From 6 Weeks to 4 Months

Scale	6 weeks → 4 months
Self-Criticism	.82***
Dependency	.83***
CES-D	.47***

Note. Table entries are Pearson product-moment correlation coefficients. DEQ = Depressive Experiences Questionnaire; CES-D = Center for Epidemiological Studies Depression Scale.
*** $p < .001$.

Table 2
Correlations of DEQ and CES-D Scales at 6 Weeks, at 4 Months

Scale	Infants at 6 weeks	Infants at 4 months
Self-Criticism & Dependency	.23**	.23**
Self-Criticism & CES-D	.50***	.67***
Dependency & CES-D	.19*	.24**

Note. Table entries are Pearson product-moment correlation coefficients. DEQ = Depressive Experiences Questionnaire; CES-D = Center for Epidemiological Studies Depression Scale.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Are Dependency and Self-Criticism Associated With Behavioral Scales or Demographics?

There were no significant correlations between means of ordinalized behavioral scales and DEQ measures. Mothers of female infants were more self-critical than those of males, $t = 2.21$, $p < .029$. DEQ measures were not associated with maternal age, education, or ethnicity.

Are Higher Maternal Self-Criticism and Dependency Scores Associated With Altered Contingencies?

We present findings associated with higher DEQ scores, using multilevel time-series analysis. There were no main effects of DEQ on means of behavioral scales (gaze, face, etc.); all findings were associations of DEQ with contingency measures. In this section we report the linear as well as the higher portion of the nonlinear effects (the right-hand side of the graphed effects) of DEQ on estimates (β) of self- and interactive contingency in Tables 3 and 4, illustrated in Figure 1. Negative signs indicate lowered contingency estimates with higher DEQ in the linear analyses and in the right-hand portion of the graph of nonlinear analyses. For each modality pairing, we report results for self-criticism and dependency, Tables 3 and 4, respectively.

In Figure 1, arrows that curve from infant to mother (mother to infant) represent mother (infant) interactive contingency; arrows that curve back into one partner's behavior represent self-contingency. The notation I→M for interactive contingency indicates that lagged infant behavior in the prior few seconds predicts maternal behavior in the current moment: Mother contingently "coordinates" with infant (and vice versa M→I). Broken arrows represent findings in which higher self-criticism and dependency scores generated lowered contingency values (compared with dyads in which mothers had lower DEQ scores for linear [L] components and compared with dyads in which mothers scored midrange DEQ sores for nonlinear [NL] components); unbroken arrows represent findings in which higher self-criticism and dependency generated higher contingency values; and absence of arrows represents no effects of DEQ. Brackets in the margins of

Table 3
Effects of Maternal 6-Week Self-Criticism (DEQ-S) on 4-Month Self- and Interactive Contingency: Linear and Nonlinear Effects

	Infant				Mother		
	β	*SE* β	*p*		β	*SE* β	*p*
Pairing (1)	**Infant gaze**				**Mother gaze**		
I→I	3.579	.068	<.001	M→M	2.474	.103	<.001
DEQ-S × I→I	**−.104**	**.053**	**.051**	DEQ-S × M→M	−.068	.077	.376
DEQ-S^2 × I→I	−.029	.044	.502	DEQ-S^2 × M→M	.053	.060	.377
M→I	.616	.154	<.001	I→M	.726	.093	<.001
DEQ-S × M→I	−.113	.111	.311	DEQ-S × I→M	−.043	.069	.530
DEQ-S^2 × M→I	−.010	.089	.912	**DEQ-S^2 × I→M**	**−.114**	**.056**	**.042**
Pairing (2)	**Infant face**				**Mother face**		
I→I	.622	.010	<.001	M→M	.532	.009	<.001
DEQ-S × I→I	.003	.008	.683	**DEQ-S × M→M**	**−.024**	**.008**	**.002**
DEQ-S^2 × I→I	−.003	.007	.671	**DEQ-S^2 × M→M**	**.021**	**.006**	**.002**
M→I	.055	.011	<.001	I→M	.142	.010	<.001
DEQ-S × M→I	.002	.009	.866	DEQ-S × I→M	.002	.007	.794
DEQ-S^2 × M→I	−.002	.008	.806	DEQ-S^2 × I→M	−.009	.007	.182
Pairing (3)	**Infant vocal quality**				**Mother face**		
I→I	.649	.009	<.001	M→M	.607	.009	<.001
DEQ-S × I→I	**.031**	**.008**	**<.001**	**DEQ-S × M→M**	**−.022**	**.007**	**.002**
DEQ-S^2 × I→I	**−.028**	**.007**	**<.001**	**DEQ-S^2 × M→M**	**.017**	**.006**	**.003**
M→I	.002	.001	<.001	I→M	1.694	.179	<.001
DEQ-S × M→I	.0003	.0004	.477	DEQ-S × I→M	.098	.154	.523
DEQ-S^2 × M→I	−.001	.0004	.065	**DEQ-S^2 ×I→M**	**−.348**	**.134**	**.009**
Pairing (4)	**Infant vocal quality**				**Mother touch**		
I→I	.664	.010	<.001	M→M	.741	.007	<.001
DEQ-S × I→I	**.018**	**.008**	**.022**	**DEQ-S × M→M**	**−.017**	**.006**	**.003**
DEQ-S^2 × I→I	**−.022**	**.007**	**.003**	DEQ-S^2 × M→M	−.007	.005	.166
M→I	.002	.002	.218	I→M	.073	.036	.044
DEQ-S × M→I	−.004	.002	.012	DEQ-S × I→M	.025	.029	.395
DEQ-S^2 × M→I	.0003	.001	.810	DEQ-S^2 × I→M	−.004	.027	.889
Pairing (5)	**Infant touch**				**Mother touch**		
I→I	.791	.007	<.001	M→M	.732	.007	<.001
DEQ-S × I→I	**−.029**	**.005**	**<.001**	**DEQ-S × M→M**	**−.020**	**.006**	**<.001**
DEQ-S^2 × I→I	**−.015**	**.005**	**.001**	DEQ-S^2 × M→M	−.003	.005	.583
M→I	.004	.001	.005	I→M	.116	.036	.001
DEQ-S × M→I	.001	.001	.338	**DEQ-S × I→M**	**.077**	**.030**	**.011**
DEQ-S^2 × M→I	−.001	.001	.500	DEQ-S^2 × I→M	−.011	.027	.674
Pairing (6)	**Infant Infant vocal quality**				**Infant Infant touch**		
IVQ→IVQ	.661	.009	<.001	ITch→ITch	.790	.007	<.001
DEQ-S × IVQ→IVQ	.014	.008	.073	**DEQ-S × ITch→ITch**	**−.028**	**.005**	**<.001**
DEQ-S^2 × IVQ→IVQ	**−.020**	**.007**	**.005**	**DEQ-S^2 × ITch→ITch**	**−.015**	**.005**	**<.001**
ITch→IVQ	.020	.008	.017	IVQ→ITch	.017	.008	.040
DEQ-S × ITch→IVQ	−.006	.007	.388	DEQ-S × IVQ→ITch	.008	.007	.220
DEQ-S^2 × ITch→IVQ	.001	.006	.127	DEQ-S^2 × IVQ→ITch	.010	.006	.127

Note. DEQ-S = Depressive Experiences Questionnaire—Self-Criticism; M = mother; I = infant; IVQ = infant vocal quality; ITch = infant touch. Standardized estimated fixed linear and nonlinear effects (β) of maternal DEQ-S (self-criticism) in interaction with M→M, I→M (or I→I, M→I), based on the "basic models." DEQ-S and DEQ-S^2 were included in all models but are not shown here. SE β = standard error of the beta; DEQ-S was centered by its mean. I→I: estimated β represents the prediction of current infant behavior from the weighted lag of infant behavior (infant self-contingency). DEQ-S × I→I: estimated β represents the effect of DEQ-S on infant self-contingency. DEQ-S^2 × I→I: estimated β represents the quadratic effect of DEQ-S on infant self-contingency. M→I: estimated β represents the prediction of current infant behavior from weighted lag of mother behavior (infant interactive contingency). DEQ-S × M→I: estimated β represents the effect of DEQ-S on infant interactive contingency. DEQ-S^2 × M→I: estimated β represents the quadratic effect of DEQ-S on infant interactive contingency. The concepts of self- and interactive contingency are not variables in the model; the model variables are the weighted lagged behaviors. Self- and interactive contingency refer to the estimated coefficients for lagged behaviors: in the models, M→I = mother behavior weighted lag (computed from model predicting current infant behavior); I→M = infant behavior weighted lag (computed from model predicting current mother behavior). For full details of basic models and computation see http://nyspi.org/Communication Sciences/index.html and Chen and Cohen (2006). All parameter entries are maximum likelihood estimates fitted using GLIMMIX Macro (Gaze) or SAS PROC MIXED (all other modalities). Negative signs indicate lower estimates of self- and interactive contingency. Significant DEQ effects are bolded.

Table 4
Effects of Maternal 6-Week Dependency (DEQ-D) on 4-Month Self- and Interactive Contingency: Linear and Nonlinear Effects

	Infant				Mother		
	β	SE β	*p*		β	SE β	*p*
Pairing (1)	**Infant gaze**				**Mother gaze**		
I→I	3.479	.061	<.001	M→M	2.578	.092	<.001
DEQ-D × I→I	−.045	.054	.403	DEQ-D × M→M	.047	.092	.607
DEQ-D² × I→I	**.065**	**.033**	**.051**	DEQ-D² × M→M	−.044	.055	.430
M→I	.567	.133	<.001	I→M	.578	.080	<.001
DEQ-D × M→I	.205	.133	.123	**DEQ-D × I→M**	**.176**	**.075**	**.020**
DEQ-D² × M→I	.063	.079	.420	DEQ-D² × I→M	.031	.043	.481
Pairing (2)	**Infant face**				**Mother face**		
I→I	.648	.009	<.001	M→M	.542	.008	<.001
DEQ-D × I→I	**−.032**	**.008**	**<.001**	DEQ-D × M→M	−.002	.077	.805
DEQ-D² × I→I	**−.043**	**.006**	**<.001**	DEQ-D² × M→M	.007	.004	.102
M→I	.041	.010	<.001	I→M	.121	.009	<.001
DEQ-D × M→I	**.041**	**.009**	**<.001**	DEQ-D × I→M	−.001	.008	.878
DEQ-D² × M→I	**.015**	**.005**	**.003**	**DEQ-D² × I→M**	**.016**	**.006**	**.011**
Pairing (3)	**Infant vocal quality**				**Mother face**		
I→I	.651	.009	<.001	M→M	.621	.008	<.001
DEQ-D × I→I	**−.031**	**.008**	**<.001**	DEQ-D × M→M	.0001	.007	.986
DEQ-D² × I→I	**−.026**	**.005**	**<.001**	DEQ-D² × M→M	.003	.004	.416
M→I	.002	.0005	<.001	I→M	1.094	.161	<.001
DEQ-D × M→I	.0002	.0004	.590	DEQ-D × I→M	.034	.145	.815
DEQ-D² × M→I	.00005	.0002	.845	**DEQ-D² × I→M**	**.298**	**.097**	**.002**
Pairing (4)	**Infant vocal quality**				**Mother touch**		
I→I	.663	.009	<.001	M→M	.733	.006	<.001
DEQ-D × I→I	**−.037**	**.008**	**<.001**	DEQ-D × M→M	−.004	.006	.544
DEQ-D² × I→I	**−.022**	**.005**	**<.001**	DEQ-D² × M→M	.001	.003	.788
M→I	.003	.002	.073	I→M	.060	.032	.062
DEQ-D × M→I	−.0004	.002	.779	DEQ-D × I→M	.001	.028	.978
DEQ-D² × M→I	−.001	.001	.542	DEQ-D² × I→M	.015	.018	.400
Pairing (5)	**Infant touch**				**Mother touch**		
I→I	.791	.006	<.001	M→M	.726	.006	<.001
DEQ-D × I→I	−.003	.006	.611	DEQ-D × M→M	−.0005	.006	.939
DEQ-D² × I→I	**−.014**	**.004**	**<.001**	DEQ-D² × M→M	.003	.003	.379
M→I	.003	.001	.022	I→M	.066	.033	.047
DEQ-D × M→I	−.002	.001	.120	DEQ-D × I→M	.012	.033	.709
DEQ-D² × M→I	.0002	.001	.825	DEQ-D² × I→M	.033	.021	.117
Pairing (6)	**Infant Infant vocal quality**				**Infant Infant touch**		
IVQ→IVQ	.659	.008	<.001	ITch→ITch	.790	.006	<.001
DEQ-D × IVQ→IVQ	**−.042**	**.008**	**<.001**	DEQ-D × ITch→ITch	−.005	.006	.383
DEQ-D² × IVQ→IVQ	**−.024**	**.005**	**<.001**	**DEQ-D² × ITch→ITch**	**−.014**	**.004**	**<.001**
ITch→IVQ	.021	.008	.009	IVQ→ITch	.014	.007	.055
DEQ-D × ITch→IVQ	.008	.007	.281	DEQ-D × IVQ→ITch	.012	.007	.077
DEQ-D² × ITch→IVQ	.002	.005	.681	**DEQ-D² × IVQ→ITch**	**.015**	**.005**	**.002**

Note. DEQ-D = Depressive Experiences Questionnaire—Dependency; M = mother; I = infant; IVQ = infant vocal quality; ITch - infant touch. Standardized estimated fixed linear and nonlinear effects (β) of maternal DEQ-D (dependency) in interaction with M→M, I→M (or I→I, M→I), based on the "basic models." DEQ-D and DEQ-D² were included in all models but are not shown here. SE β = standard error of the beta; DEQ-S was centered by its mean. I→I: estimated β represents the prediction of current infant behavior from the weighted lag of infant behavior (infant self-contingency). DEQ-D × I→I: estimated β represents the effect of DEQ-D on infant self-contingency. DEQ-D² × I→I: estimated β represents the quadratic effect of DEQ-D on infant self-contingency. M→I: estimated β represents the prediction of current infant behavior from the weighted lag of mother behavior (infant interactive contingency). DEQ-D × M→I: estimated β represents the effect of DEQ-D on infant interactive contingency. DEQ-D² × M→I: estimated β represents the quadratic effect of DEQ-D on infant interactive contingency. The concepts of self- and interactive contingency are not variables in the model; the model variables are the weighted lagged behaviors. Self- and interactive contingency refer to the estimated coefficients for lagged behaviors: in the models, M→I = mother behavior weighted lag (computed from model predicting current infant behavior); I→M = infant behavior weighted lag (computed from model predicting current mother behavior). For full details of basic models and computation see http://nyspi.org/Communication Sciences/index.html and Chen and Cohen (2006). All parameter entries are maximum likelihood estimates fitted using GLIMMIX Macro (Gaze) or SAS PROC MIXED (all other modalities). Negative signs indicate lower estimates of self- and interactive contingency. Significant DEQ effects are bolded.

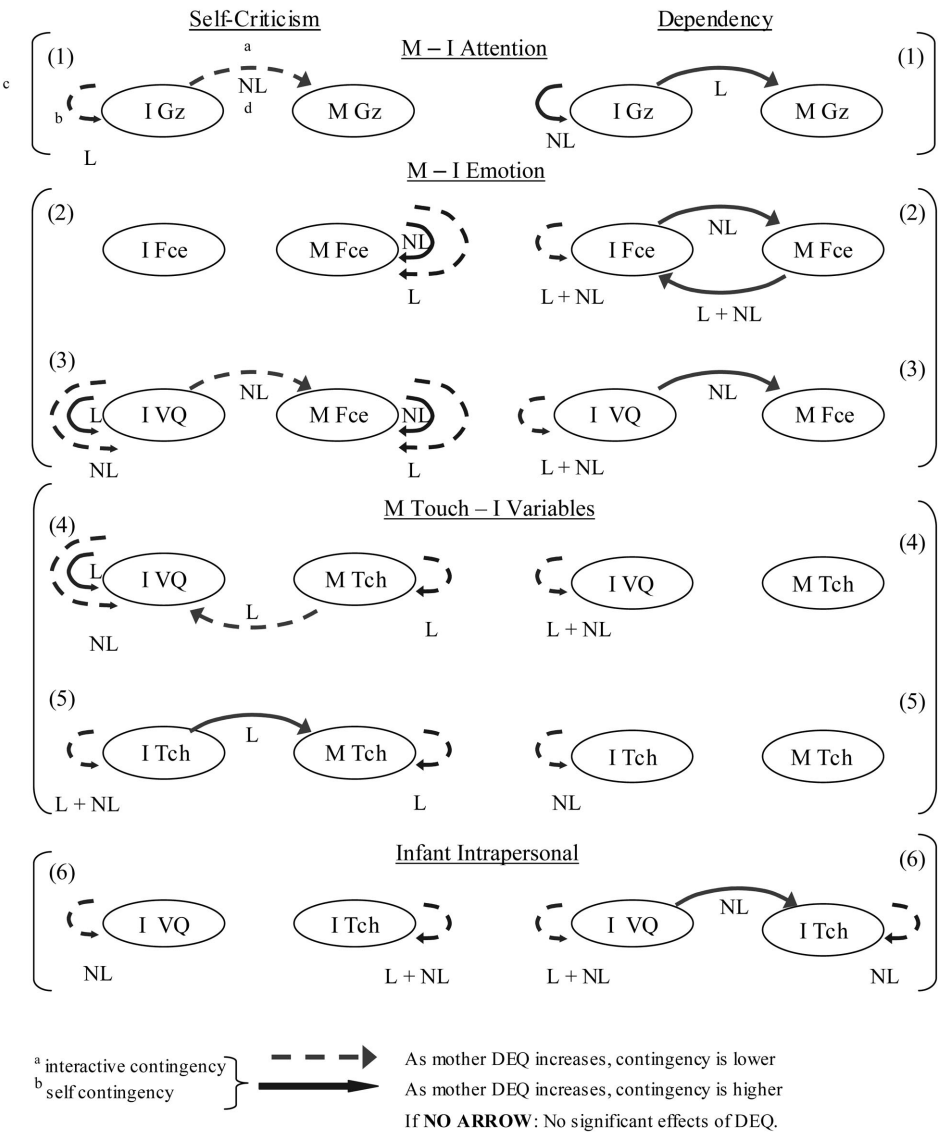

Figure 1. Linear (L) and nonlinear (NL) effects of higher maternal self-criticism and dependency on self- and interactive contingency.

Figure 1 demarcate four domains: attention (pairing 1), emotion (2 and 3), maternal touch in relation to infant behavior (4 and 5), and infant intra-active organization of vocal quality and touch (6).

(1) Infant Gaze – Mother Gaze

Self-Contingency. More (vs. less) self-critical mothers had infants with lowered gaze self-contingency (Table 3). More dependent mothers had infants with heightened gaze self-contingency (compared with mothers scoring midrange in DEQ; see Table 4, Figure 1).

Interactive contingency. More self-critical mothers lowered their gaze coordination with infant shifts of gaze on/off mother's face (compared with mothers scoring midrange in DEQ). More (vs. less) dependent mothers heightened their gaze coordination with infant gaze on/off.

(2) Infant Face – Mother Face

Self-Contingency. More self-critical mothers showed opposite signs of lowered linear, but heightened nonlinear, facial self-contingency. Graphing revealed that the linear relation characterized most mothers: More self-critical mothers had lowered facial self-contingency. However, for mothers with the highest self-criticism scores, self-contingency began to increase. More depen-

dent mothers had infants with lowered facial self-contingency (compared with mothers scoring lower, and midrange in DEQ).

Interactive contingency. Self-criticism yielded no findings. More dependent mothers and their infants heightened their facial coordination with the partner's positive and negative facial shifts (for infants and mothers, compared with dyads where mothers scored midrange in DEQ; compared with infants of lower DEQ mothers).

(3) Infant Vocal Quality – Mother Face

Self-Contingency. More self-critical mothers showed lowered linear, but heightened nonlinear, facial self-contingency. Graphing revealed that the linear relation characterized most mothers: More self-critical mothers had lowered facial self-contingency. However, for the most self-critical mothers, self-contingency began to increase. Infants of more self-critical mothers showed heightened linear, but lowered nonlinear, vocal quality self-contingency. Graphing revealed that the linear relation characterized most infants: More self-critical mothers had infants with heightened vocal quality self-contingency. However, for infants of the most self-critical mothers, self-contingency began to decrease. More dependent mothers had infants with lowered vocal quality self-contingency (compared with infants of mothers with lower, and midrange DEQ).

Interactive contingency. More self-critical mothers lowered their contingent facial coordination with infant vocal quality (compared with mothers scoring midrange in DEQ). Infants of more self-critical mothers had a nonsignificant trend ($p = .065$) toward reciprocally lowered vocal quality coordination with mother face. More dependent mothers heightened their facial coordination with infant shifts of vocal quality (compared with mothers scoring midrange in DEQ).

(4) Infant Vocal Quality – Mother Touch

Self-Contingency. More (vs. less) self-critical mothers showed lowered touch self-contingency. Infants of more self-critical mothers showed heightened linear, but lowered nonlinear, vocal quality self-contingency. Graphing revealed that the linear relation characterized most infants: More self-critical mothers had infants with heightened vocal quality self-contingency. However, for infants of the most self-critical mothers, self-contingency began to decrease. Infants of more dependent mothers showed lowered infant vocal quality self-contingency (compared with infants of mothers scoring lower, and midrange in dependency).

Interactive contingency. Infants of more (vs. less) self-critical mothers lowered their vocal quality coordination with maternal touch (from affectionate to intrusive). Although statistically significant, graphing revealed that this is a subtle effect. We interpreted with caution.

(5) Infant Touch – Mother Touch

Self-Contingency. More (vs. less) self-critical mothers showed lowered touch self-contingency. Infants of more self-critical mothers showed lowered touch self-contingency (compared with infants of mothers scoring lower, and midrange in DEQ). Infants of more dependent mothers showed lowered touch self-contingency (compared with infants of mothers scoring midrange in DEQ).

Interactive contingency. More (vs. less) self-critical mothers heightened their touch coordination with infant touch.

(6) Intrapersonal Infant Vocal Quality – Infant Touch

Self-Contingency. Infants of more self-critical mothers showed lowered vocal quality self-contingency (compared with infants of mothers scoring midrange in DEQ), and lowered touch self-contingency (compared with infants of mothers with lower, and midrange DEQ). Infants of more dependent mothers showed lowered vocal quality self-contingency (compared with infants of mothers with lower, and midrange DEQ), and lowered touch self-contingency (compared with infants of midrange DEQ mothers).

Infant intra-active contingency. Across the group, the association between vocal quality and touch was positive: The more positive the infant's vocal quality, the more infant touch, and vice versa. For infants of more dependent mothers, this effect of vocal quality on touch was heightened (compared with infants of mothers with midrange DEQ).

In summary, across the two DEQ measures, counting linear and nonlinear effects, there were 21 (of 28 possible) infant self-contingency effects, 6 (of 20 possible) mother self-contingency effects (self-criticism only), 6 (of 20 possible) mother interactive contingency effects, 3 (of 20 possible) infant interactive contingency effects, and 1 (of 8 possible) infant intra-active effects. Infants showed over three times the number of self-contingency findings as mothers, and mothers showed two times the number of interactive contingency findings as infants. Infant self-contingency was lowered in 8 of 10 findings with higher maternal self-criticism, and in 10 of 11 findings with higher maternal dependency. Maternal self-contingency was lowered in 4 of 6 findings with higher maternal self-criticism. Self-criticism generated both lowered and heightened interactive contingency; dependency generated only heightened.

Are Alterations in Contingency Associated With the Low Pole of DEQ Scores Similar to Those Associated With the High Pole? Nonlinear Analyses

The previous section described findings of dyads in which mothers endorsed higher self-criticism or dependency. We now return to the nonlinear analyses (Tables 3 and 4) to interpret findings at the low pole of DEQ. Where significant, nonlinear analyses show that alterations in self- and interactive contingency associated with movement toward the low pole of DEQ scores are similar (in direction but not necessarily in absolute amount) to those associated with the high pole (compared with dyads with midrange scores). Roughly half the DEQ effects were nonlinear: 12/21 infant and 2/6 mother (self-criticism) self-contingency, 4/6 mother and 1/3 infant interactive contingency, and 1/1 infant intra-active contingency findings.

(1) Infant Gaze – Mother Gaze

Self-Contingency. As maternal dependency moved toward high and low poles, infants showed similar increases in gaze self-contingency (compared with dyads in which mothers scored midrange in DEQ).

Interactive contingency. As maternal self-criticism moved toward the high and low poles, mothers showed similar decreases in their gaze coordination with infant gaze on/off mother's face (compared with mothers with midrange self-criticism).

(2) Infant Face – Mother Face

Self-Contingency. As maternal self-criticism moved toward the high and low poles, mothers showed similar increases in facial self-contingency; as maternal dependency moved toward the high and low poles, infants showed similar decreases in facial self-contingency (both compared with dyads in which mothers scored midrange in DEQ).

Interactive contingency. As maternal dependency moved toward the high and low poles, both mothers and infants showed similar increases in facial coordination with the partner's facial quality (compared with dyads in which mothers scored midrange in DEQ).

(3) Infant Vocal Quality – Mother Face

Self-Contingency. As maternal self-criticism moved toward the high and low poles, mothers showed similar increases in facial self-contingency, and infants showed similar decreases in vocal quality self-contingency; as maternal dependency moved toward the high and low poles, infants showed similar decreases in vocal quality self-contingency (compared with dyads in which mothers scored midrange in DEQ).

Interactive contingency. As maternal self-criticism moved toward high and low poles, mothers showed similar decreases in facial coordination with infant vocal quality; as maternal dependency moved toward high and low poles, mothers showed similar increases in facial coordination with infant vocal quality (compared with dyads in which mothers scored midrange in DEQ).

(4) Infant Vocal Quality – Mother Touch

Self-Contingency. As maternal self-criticism and dependency moved toward the high and low poles, infants showed similar decreases in vocal quality self-contingency (compared with dyads in which mothers scored midrange in DEQ).

(5) Infant Touch – Mother Touch

Self-Contingency. As maternal self-criticism and dependency moved toward the high and low poles, infants showed similar decreases in touch self-contingency (compared with dyads in which mothers scored midrange in DEQ).

(6) Intrapersonal Infant Vocal Quality – Infant Touch

Self-Contingency. As maternal self-criticism and dependency moved toward the high and low poles, infants showed similar decreases in touch and vocal quality self-contingency (compared with dyads in which mothers scored midrange in DEQ).

Infant intra-active contingency. As maternal dependency moved toward the high and low poles, infants showed similar increases in touch coordination with vocal quality (compared with dyads in which mothers scored midrange in DEQ).

Discussion

A personality approach to depressive experience (DEQ; Blatt, 2004) was used to study associations between 6-week maternal self-criticism and dependency and 4-month mother–infant self- and interactive contingency. After noting descriptive information, we describe the meaning of higher and lower contingencies, and evaluate our hypothesis that distress biases the system toward both heightened and lowered contingencies. We then describe the associations of higher self-criticism and dependency with these contingencies and explore findings in relation to the work of Blatt and colleagues. Our question of whether contingency patterns of dyads at the low pole of self-criticism and dependency endorsement look similar to those at the high pole is addressed next. We then interpret our self- and interactive contingency findings as forms of self- and interactive regulation. Finally, limitations of the study and implications for early intervention are noted.

Descriptive Information

Associations between DEQ and maternal age, education, and ethnicity were absent. But mothers of female infants were more self-critical than those of males, possibly because of feelings of responsibility or enmeshment with daughters. There were no associations between DEQ and means of the ordinalized behavioral scales. Thus, higher (vs. lower) DEQ dyads did not differ in gaze, in degree of positivity of facial or vocal quality, or in touch patterns, either in correlational analyses or in main effects of multilevel time-series models. Instead the differences were found in patterns of self- and interactive contingency.

The Meaning of Higher and Lower Degrees of Self- and Interactive Contingency

Infants perceive temporal sequences, contingencies, and degrees thereof, and come to expect when events will occur (DeCasper & Carstens, 1980; Haith et al., 1988; Watson, 1985). Varying degrees of self-contingency generate expectancies regarding the predictability of one's own behavior. Lowered self-contingency is translated into the metaphor of "self-destabilization." Lowered infant self-contingency, for example, may make it harder for mothers to anticipate the infant's ongoing behavioral stream and for infants to anticipate their own behaviors. Heightened self-contingency indicates behavior tending toward an overly steady, nonvarying process, translated into the metaphor of "self-stabilization."

Interactive contingency is translated into the metaphor of expectancies of how predictable the partner is from one's own prior behavior, and vice versa: metaphorically, expectancies of "how I affect you," and "how you affect me." In prior work, we interpreted high interactive contingency as an effort to create more predictability in contexts of novelty, challenge, or threat, translated into "activation" or "vigilance," and low coordination as "inhibition" or "withdrawal" (Jaffe et al., 2001). Vigilance for social signals is an important aspect of social intelligence, likely an evolutionary advantage with uncertainty or threat (Ohman, 2002). The partner's lowered interactive contingency compromises the individual's ability to anticipate consequences of his own actions: lowered interactive agency. Infant expectancies of different patterns of contingency constitute one process by which maternal

distress might be transmitted to the infant and alter the trajectory of development.

The Hypothesis That Distress Biases the System Toward Both Heightened and Lowered Contingency

We hypothesized that, across the system of both partners and all communication modalities, maternal distress biases the system toward both heightened contingency values (in some modalities) and lowered (in others). Where linear and nonlinear effects had opposite signs, we used the linear effects, which characterized most participants, to evaluate this hypothesis.

Associations of higher maternal self-criticism with maternal interactive contingency were consistent with our hypothesis: Mothers showed heightened coordination with infants through touch, but lowered through gaze and face. These findings are consistent with Jaffe et al. (2001), in which both high and low degrees of interactive contingency predicted insecure attachment. However, associations of higher maternal self-criticism with maternal self-contingency were not consistent with this hypothesis: Overall, contingencies were lowered (in touch and, for most participants, in face). Associations of higher maternal self-criticism with infant interactive contingency did not fit our hypothesis: There was only one finding. Associations of higher maternal self-criticism with infant self-contingency did fit our hypothesis. Infant self-contingency was lowered in gaze, touch, and vocal quality (paired with infant touch) but heightened in vocal quality paired with mother face and touch (for most participants).

Our hypothesis did not fit associations of maternal dependency with interactive contingency: Both partners were heightened, a mutually vigilant system. Infant self-contingency findings were technically consistent with our hypothesis: both heightened, in gaze, as well as lowered, in face, vocal quality, and touch. But infant self-contingency was lowered in 10 of 11 findings, thus generating primarily a picture of destabilization. Maternal self-contingency findings were absent.

Combining effects of maternal self-criticism and dependency on infant self-contingency, of 28 linear and nonlinear analyses, infant self-contingency was lowered in 18 of 21 findings, the most robust finding of the study. Thus, with maternal distress, infant self-contingency was primarily destabilized, a pattern also evident with maternal depression (Beebe et al., in press).

Conjectures of Different Contingency Patterns Associated With Self-Criticism and Dependency

Without prior infant literature to generate specific hypotheses, we conjectured that self-criticism would show lowered maternal interactive contingency in emotion modalities, consistent with an avoidant, dismissive emotional style, and heightened maternal self-contingency across modalities, consistent with the emphasis on self-definition. These conjectures were partially upheld. Self-criticism did show lowered maternal facial interactive contingency. However, maternal self-contingency was lowered in touch and in face (for most participants).

We conjectured that maternal dependency would be associated with heightened maternal emotional interactive contingency, the hallmark of this personality configuration, and with lowered maternal emotional self-contingency, exacerbating emotional vigilance. These conjectures were also partially upheld. Dependency showed exclusively heightened interactive contingency findings, with two (of three) in the emotional realm of the face (the third in gaze). However, maternal self-contingency findings were absent. The disturbance is thus exclusively interpersonal, confirming Blatt (2004).

The Picture of Higher Maternal Self-Criticism

Gaze. More self-critical mothers lowered their gaze coordination with infant gaze on/off (see Figure 1, pairing 1), an attentional withdrawal, not paying as much attention to infant visual availability as mothers with midrange self-criticism. Attention to the partner's direction of gaze is a critical foundation of the mother–infant face-to-face encounter (Brazelton, Koslowski, & Main, 1974; Tronick, 1989). Self-critical mothers may misinterpret infant gaze aversion as rejection or as a failure in mothering, or they may be preoccupied with feelings of inadequacy, any of which might disturb their monitoring of infant visual availability (Kaminer et al., 2007). Additionally, lowered infant gaze predictability may make it harder for mothers to anticipate and coordinate with infant gaze, leading to lowered maternal gaze coordination.

Face and vocal quality. More self-critical mothers lowered facial coordination with infant vocal quality shifts (pairing 3), an emotional withdrawal. These mothers were less likely to become facially positive as infants became more vocally positive and less likely to show facial concern as infants became vocally more distressed, thus lowering infant interactive efficacy. Clinically this manifests as a disturbance in maternal ability to share positive moments and in maternal facial empathy with infant vocal distress. These mothers may be too preoccupied, or may feel inadequate, to engage in this emotional arena, similar to the lowered empathy of self-critical adults (Zuroff & Mongrain, 1987). Mothers have varying modality preferences or sensitivities (Delgado, Messinger, & Yale, 2002; Keller et al., 1999). Self-critical mothers may be less able to coordinate facially with infant vocal quality (whereas depressed mothers in these data showed heightened facial coordination with infant vocal quality [Beebe et al., in press]).

Infants showed complex vocal quality self-contingency findings that may be related to maternal emotional withdrawal. With increasing maternal self-criticism, most infants increased vocal quality self-contingency, interpreted as a self-stabilizing coping effort. However, for infants of the most self-critical mothers, self-contingency began to decrease, a self-destabilization. Lowered infant vocal quality self-contingency may make it harder for the most self-critical mothers to anticipate and coordinate with infants.

Mothers also showed complex facial self-contingency findings (pairings 2, 3). With increasing self-criticism, most mothers showed lowered facial self-contingency, a destabilization. However, for the most self-critical mothers, facial self-contingency began to increase, whereas facial coordination with infant vocal quality decreased (pairing 3), an imbalance between self- and interactive contingency. In this pattern, the most self-critical mothers began to be more facially stable, a mode of "closing up one's face." Tronick's (1989) description of infants of depressed mothers as withdrawing from engagement into preoccupation with self-regulation is analogous.

Touch. Self-critical mothers increased contingent touch coordination with infant touch (pairing 5). Across the group, the

positive correlation indicated that as infants touched more, maternal touch patterns were more affectionate and vice versa. This association was heightened for self-critical dyads. At the same time, self-critical mothers showed lowered touch self-contingency, a self- versus interactive contingency imbalance. Thus, mothers were overly coordinated with infants at the expense of self-stability. Self-critical mothers may "overcompensate" through touch contingency for their withdrawal through face and gaze (see Moreno et al., 2006). They have difficulty tuning in to the emotional sphere but can relate on the more concrete level of touch. Self-critical mothers showed heightened touch coordination with infant touch shifts despite lowered infant touch self-contingency, which may make it harder for mothers to anticipate and coordinate with infants. Thus, self-critical mothers seemed to be working hard to coordinate touch patterns with infant touch. Reciprocally, infant destabilized touch self-contingency may be related to maternal heightened touch coordination.

Infants of self-critical mothers lowered their vocal quality coordination with maternal touch (pairing 4), precisely the modality in which mothers were overly responsive (pairing 5). This infant finding is interpreted with caution because of a small, albeit significant, association. This pattern constitutes a dyadic mother "approach" (through touch) and infant "withdrawal" from maternal touch. Infant vocal quality self-contingency findings (pairing 4) were complex. For most infants, with increasing maternal self-criticism, infants heightened their vocal quality self-contingency, interpreted as a coping effort to self-stabilize. However, for infants of the most self-critical mothers, infant vocal quality self-contingency was lowered, a "self-destabilization."

Summarizing the picture of higher maternal self-criticism, the mother's lowered gaze coordination with infant gaze, lowered facial coordination with infant vocal quality, in conjunction with heightened touch coordination with infant touch, are interpreted as the self-critical mother's difficulty joining the infant's attention structure, difficulty entering the infant's emotional ups and downs, and compensating by becoming overly involved with touch, a more concrete modality than face or gaze. Together these mothers and infants generated a pattern of mother "approach" through touch, but infant "withdrawal" from maternal touch. Every measure of self-contingency was altered by maternal self-criticism (except face for infants and gaze for mothers).

These findings are consistent with Blatt and colleagues' descriptions of self-critical individuals as preoccupied by self-definition, compromising relatedness (Blatt et al., 1992). These mothers stay "separate" from infants in attentional and emotional realms, compromising infant interactive efficacy. Where mothers may compensate, through heightened touch coordination, infants withdraw, lowering coordination with mother touch. Thus, similar to their mothers, infants also seem to stay "too separate."

The Picture of Higher Maternal Dependency

Gaze. More dependent mothers heightened coordination with infant on-off gaze, an attentional vigilance, opposite that of self-critical mothers (see pairing 1, Figure 1). Maternal gaze vigilance may reflect excessive maternal concern with infant (visual) availability. Heightened infant gaze self-contingency indicates that infants were more likely to stay in the same gaze state, a more slowly moving process between gaze on and off, with which mothers closely coordinated (however, no differences occurred in amount of gaze on or off in higher DEQ infants). Longer gaze at mother is likely to be more arousing for these infants; longer gaze off provides more time to down-regulate arousal (Field, 1981). Because all interactive contingency findings were heightened, a social vigilance likely accompanied by emotional activation (Ohman, 2002), we infer that infants are working hard at arousal regulation through stabilizing gaze self-contingency.

Face and vocal quality. More dependent mothers heightened facial coordination with infant facial and vocal quality (pairings 2, 3), an emotional vigilance, opposite self-critical mothers. Infants reciprocally heightened facial coordination with maternal facial shifts (pairing 2), a mutual facial vigilance. Thus, both partners were overly reactive to the other's affective shifts. Symmetrical facial vigilance may become a dyadic "state" of its own, sensed and known by both partners, as a particular mode of heightened engagement (Tronick, 1998). Infants were facially overly coordinated with mothers, at the expense of facial self-stability, an imbalance accentuating interpersonal vigilance. Whereas lowered infant facial/vocal quality self-contingency may make it harder for mothers to anticipate and coordinate, dependent mothers nevertheless heightened their contingent coordination with infant facial/vocal shifts. Thus, dependent mothers seemed to be working hard to coordinate with infant shifts. Reciprocally, infant destabilized face and vocal quality self-contingency may be related to maternal facial vigilance.

Maternal vigilant facial coordination can be described as emotional "hovering." Mothers may be overly "thrilled" when infants are positive and overly disappointed when infants are negative, as if mothers are overusing the infant's affective state to regulate their own, perhaps to see if they are loved. For their part, infants of more dependent mothers sense a greater probability of contingent consequences of their facial shifts on maternal facial shifts, a heightened "efficacy" that may set the stage for the child's eventual feeling of having "too great" an impact on the mother's emotional states.

Infant intra-active vocal quality – touch. Infants of dependent mothers showed heightened effects of infant vocal quality on infant touch (pairing 6). Across the group, this positive correlation indicates that the more positive infant vocal quality, the more likely infant touch and vice versa. This heightened correlation in infants of dependent mothers suggests a more fragile mechanism. As vocal quality becomes more positive, infants of more dependent mothers are more likely to touch than infants of less dependent mothers; but as infants become vocally distressed, infants of dependent mothers are less likely to touch. Thus, the regulation of touch becomes too dependent on vocal quality. Particularly when vocal quality is more distressed, infant touch is less available: a disturbance in infant capacity to down-regulate vocal distress.

Summarizing the picture of higher maternal dependency, interactive contingency was uniformly heightened, but more so for mothers than infants. This dyadic social vigilance is likely accompanied by emotional activation (Ohman, 2002). Maternal heightened gaze and facial coordination indicate excessive maternal concern about the infant's visual and emotional availability and excessive involvement in the infant's emotional (facial/vocal) ups and downs. Mothers and infants generated mutual facial vigilance, both overly reactive to the other's affective shifts. Infants showed robustly lowered self-contingency in face, vocal quality, and

touch, interpreted as self-destabilization (with one exception, overly stabilized gaze). Whereas every infant measure of self-contingency was altered by maternal dependency, maternal self-contingency findings were strikingly absent. In the infant intrapersonal pattern, when vocal quality was more distressed, infant touch was less available, a disturbance in infant capacity to down-regulate vocal distress.

The picture of reciprocal emotional vigilance in more dependent mothers and their infants is consistent with Blatt's (2004) description of dependent individuals as "empty" and "needy" of emotional supplies from their partners. The striking absence of maternal self-contingency findings is consistent with Blatt and colleagues' theory that the disturbance in dependent individuals is specifically interpersonal. It is remarkable that infants also show the vigilant facial pattern, a dyadic symmetry. Dependent mothers' preoccupation with maintaining attentional as well as emotional engagement is a picture of "hovering" that may interfere with the infant's own "room to grow" (see Bergman & Fahey, 1999). The symmetrical infant preoccupation with facial coordination, at the expense of facial self-contingency, may be consistent with Blatt's (2004) findings that children of more dependent mothers have more difficulty with individuation.

Evaluating High and Low Poles of Maternal Self-Criticism and Dependency

Because self-report scales are vulnerable to denial (Shedler et al., 1993), we conjectured that very low DEQ scores may be associated with communication difficulties similar to those of very high scores. Testing this notion with nonlinear analyses, approximately half the findings were nonlinear. Dyads in which mothers endorsed both high and low DEQ poles showed similar patterns of altered contingency, compared with dyads in which mothers had midrange scores, described next.

At both high and low poles of maternal self-criticism scores (compared with midrange scores), infants showed lower self-contingency (vocal quality, touch); mothers showed higher self-contingency (face); and mothers lowered gaze coordination with infant gaze and lowered facial coordination with infant vocal quality. At both high and low poles of maternal dependency scores, infants showed lower self-contingency (face, vocal quality, touch) and higher self-contingency (gaze), mothers heightened facial coordination with infant facial/vocal quality, infants reciprocally heightened facial coordination with maternal facial quality, and the intra-active effect of infant vocal quality on infant touch was heightened.

Although we are intrigued by these nonlinear findings indicating difficulty at the very low DEQ pole, we remain cautious. Some mothers reporting very few or no symptoms may indeed be less vulnerable, whereas others may be using denial. Current research has reported contradictory findings (Pickens & Field, 1993; Shedler et al., 1993; Tronick et al., 1997; Weinstein & Kahn, 1955). Long-term consequences for infant development in dyads where mothers have very low distress scores is unclear (Lyons-Ruth, Zoll, Connell, & Grunebaum, 1986). This debate deserves further consideration.

Implications of Contingency Findings for the Concept of "Regulation"

The concept of regulation is defined differently in varying research traditions (Campos, Frankel, & Camras, 2004; Cole, Martin, & Dennis, 2004; Davidson, Jackson, & Kalin, 2000). Our contingency measures, assessing predictability of behavior over time, qualify as one definition of regulation (Cohn & Tronick, 1988; Jaffe et al., 2001; Sander, 1977). Of Cole et al.'s (2004) review of definitions of regulation, our approach fits their "analysis of temporal relations" using time-based methods, illustrated with the work of Cohn and Tronick (1988), "well-suited to inferring that each person's behavior regulates that of the partner" (p. 324). Thus, we construe our self- and interactive contingency findings as forms of self- and interactive regulation. Although this approach is familiar for interactive regulation, it is less so for self-regulation (but see Downey & Coyne, 1990; McCleary & Hay, 1980; Thomas & Malone, 1979; Warner, 1992). There is little agreement on the definition and mechanism of self-regulation (Fox, 1994). Whereas one frequent definition of self-regulation is the activation/dampening of arousal and capacity to down-regulate negative affect (Kopp, 1989; Stifter, 2002), the autocorrelation measure of self-predictability is more abstract and more general. The advantage of framing the results as regulation is that our findings can then be related to a large literature on self- and interactive regulation (see Beebe, Jaffe, et al., 2007; Beebe & Lachmann, 2002; Beebe et al., in press; Cohn & Tronick, 1988; Sander, 1977; Tronick, 1989).

Limitations

Because we did not covary the effects of 6-week self-criticism and dependency as we investigated their respective associations with 4-month contingencies (the shared variance was small: 5.6%), we cannot evaluate the specificity of the effects of 6-week dependency or self-criticism on 4-month contingencies. Furthermore, although we used 6-week maternal DEQ measures in relation to 4-month contingencies, the large correlations between 6-week and 4-month dependency and self-criticism (.83 and .82, respectively) suggest that 6-week vulnerabilities are likely to continue at 4 months, a considerable stability in this dimension of maternal personality. The 4-month contingency pictures are thus likely to be a function of 4-month as well as of 6-week maternal vulnerabilities, but we did not investigate whether the 4-month DEQ measures mediate the effects of the 6-week DEQ measures. Nevertheless, women identified as vulnerable at 6 weeks are likely to have dyadic communication difficulties at 4 months, important for primary prevention.

Our analyses address the dyadic organization of self- and interactive contingency and do not evaluate how infants may contribute to difficulties, separate from the dyad. An independent measure of infant organization would be required. For example, neonates with more difficult state regulation have mothers who are more likely to report depressive symptoms at 6 weeks (Murray & Cooper, 1997).

Significance for Mental Health and Intervention

Whereas symptom approaches assess intensity of distress, personality approaches can inform the clinician of different meanings

that a particular transaction might hold for a mother, improving specificity of interventions (see Beebe, 2003; Kaminer et al., 2007; Stern, 1995). For example, self-critical mothers can be helped to pay more attention to the infant's necessary cycling of gaze on and off, while the clinician holds in mind the mother's potential feelings of inadequacy when her infant looks away. In contrast, dependent mothers can be helped to be less sensitive to moments when infants look away, and to trust that the infant will return, while the clinician holds in mind the mother's potential feelings of emptiness and intense need for engagement from her infant.

In summary, 6-week maternal self-criticism and dependency generated strikingly different pictures of 4-month face-to-face communication difficulties, which are consistent with the theories of Blatt and colleagues, and which have different implications for intervention strategies.

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