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SIX-WEEK POSTPARTUM MATERNAL DEPRESSIVE SYMPTOMS AND 4-MONTH MOTHER–INFANT SELF- AND INTERACTIVE CONTINGENCY

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ABSTRACT: Associations of 6-week maternal depressive symptoms [Center for Epidemiological Studies Depression Scale (CES-D)] with 4-month mother–infant self- and interactive contingency patterns during face-to-face play were investigated in 132 dyads. Self- and interactive contingency (auto- and lagged cross-correlation, respectively) were assessed by multilevel time-series analysis. Infant and mother gaze, facial and vocal affect, touch, and spatial orientation behaviors were coded second-by-second from split-screen videotape, and a multimodal measure of facial–visual "engagement" was constructed, generating nine modality pairings. With higher CES-D, the *self-contingency* of both partners was lowered in most modalities. With higher CES-D, *interactive contingency* values were both heightened (in some modalities) and lowered (in others), varying by partner. These results are consistent with an optimal midrange model. With higher CES-D, interactive contingency showed the following patterns: (a) Mothers and their infants had a reciprocal orientational sensitivity; (b) mothers and infants manifested a reciprocal intermodal discordance in attention versus affect coordination, *lowering* gaze coordination, but *heightening* affective coordination; (c) infants heightened, but mothers lowered, touch coordination with partner touch—an "infant approach–mother withdraw" touch pattern. Nonlinear analyses indicated that altered self- and interactive contingency were similar at both the low ("denial") as well as the high ("endorsement") poles of depressive symptoms, in half the findings. These complex, multimodal findings define different aspects of communication disturbance, with relevance for therapeutic intervention.

This research was supported by NIMH Grant MH56130, the Psychoanalytic Fund, the Kohler Foundation, the Edward Aldwell Mother–Infant Research Fund, and the LA Infant Research and Psychoanalysis Fund. We thank our filming/coding team: Caroline Flaster, Donna Demetri-Friedman, Helen Demetriades, Nancy Freeman, Patricia Goodman, Michaela Hager-Budny, Sara Hahn-Burke, Elizabeth Helbraun, Allyson Hentel, Tammy Kaminer, Sandra Triggs Kano, Limor Kaufman-Balamuth, Greg Kushnick, Lisa Marquette, Jill Putterman, Jane Roth, Shanee Stepakoff, and Lauren Ellman. We thank our assistants Sara Markese, Michael Ritter, Alla Chavarga, Alina Pavlakos, Adrianne Lange, Sarah Miller, Kari Gray, Jennifer Lyne, Annee Ackerman, Fernanda Lucchese, Sam Marcus, Kara Levin, Joseph McGowan, Matthew Kirkpatrick, Lauren Cooper, Helen Weng, Iskra Smiljanic, and Christy Meyer. We thank Katherine Weinberg, Edward Tronick, Doris Silverman, Frank Lachmann, Anni Bergman, Lin Reicher, George Downing, Estelle Shane, and the Monday afternoon seminar.
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INFANT MENTAL HEALTH JOURNAL, Vol. 29(5), 442–471 (2008)

Published online in Wiley InterScience (www.interscience.wiley.com).
DOI: 10.1002/imhj.20191

RESUMEN: En un grupo de 132 díadas se investigaron las asociaciones entre los síntomas de depresión maternal a las 6 semanas (CES-D) y patrones de 4 meses de contingencia propia e interactiva entre la madre y el infante durante el juego cara a cara. Las contingencias propia e interactiva (propia y demorada correlación mutua, respectivamente) fueron evaluadas por medio de un análisis a varios niveles y en una serie de momentos temporales. La mirada del infante y la madre, el afecto facial y vocal, el acto de tocarse, y las conductas de orientación espacial fueron codificadas sección por sección, a partir de una videograbación con pantalla dividida, y una medida multimodal de contacto facial y visual fue construída, todo lo cual generó 9 pareamientos de modalidades. En los casos de más altos niveles de CES-D, la autocontingencia de cada una de las partes bajó en la mayoría de las modalidades. En los casos de más altos niveles de CES-D, los valores de contingencia interactiva subieron en ambas personas (en algunas modalidades) y bajaron (en otras), según cada individuo, consistente con un modelo intermedio óptimo. En los casos de niveles más altos de CES-D, la contingencia interactiva mostró los siguientes patrones: (1) las madres y sus infantes tenían una sensibilidad de orientación recíproca; (2) las madres y los infantes manifestaron una discordancia intermodal recíproca en cuanto a la coordinación de la atención vs. el afecto, la coordinación del acto de bajar la mirada pero aumentar la coordinación afectiva; (3) mientras que los infantes aumentaron la coordinación del acto de tocarse cuando la otra persona los tocó, las madres bajaron dicha coordinación: un patrón de tocarse del tipo de "el infante se acerca, la madre se desentiende." Los análisis no lineales indicaron que las alteradas probabilidades, propia e interactiva, fueron similares en ambos extremos de los síntomas depresivos, el bajo ("negación") y el alto ("aprobación"), en la mitad de los resultados. Estos complejos resultados multimodales definen diferentes aspectos de los trastornos de la comunicación, y presentan relevancia para la intervención terapéutica.

RÉSUMÉ: Les associations de symptômes maternels dépressifs à 6 semaines (CES-D) avec les patterns d'auto-contingence et de contingence interactive mère-nourrisson de quatre mois durant le jeu de face-à-face ont été étudiée chez 132 dyades. L'auto-contingence et la contingence interactive (auto-corrélation et inter-corrélation décalée, respectivement) ont été évaluées par une analyse à multi-niveau. Le regard de la mère et du nourrisson, l'affect vocal et facial, le toucher et les comportements d'orientation spatiale ont été codés seconde par seconde à partir d'une vidéo multi-écran et une mesure multi-nodale d' "engagement" facial-visuel a été construite, générant 9 couples paires de modalité. Avec un CES-D plus élevé l'*auto-contingence* des deux partenaires était abaissée dans la plupart des modalités. Avec un CES-D plus élevé, les valeurs de *contingence interactive* étaient à la fois accentuées (pour certaines des modalités) et décrues (pour d'autres), variant suivant le partenaire, de manière consistante avec un modèle optimal de milieu de gamme. Avec une CES-D plus élevé, la contingence interactive a fait état des patterns suivants : (1) les mères et leurs nourrissons avaient une sensibilité d'orientation réciproque ; (2) les mères et les nourrissons ont fait preuve d'une discordance intermodale réciproque dans l'attention par rapport à la coordination de l'affect, *diminuant* la coordination du regard mais *augmentant* la coordination affective ; (3) Les nourrissons augmentaient, mais les mères abaissaient, la coordination du toucher avec le toucher du partenaire : un pattern de toucher "approche du nourrisson – retrait de la mère". Des analyses non linéaires ont indiqué que les auto-contingences et contingences interactives altérées étaient semblables au pôle bas ("rejet") ainsi qu'au pôle élevé ("appui") des symptômes dépressifs, dans la moitié des résultats. Ces résultats multi-modales complexes définissent différents aspects de troubles de la communication, avec une pertinence pour l'intervention thérapeutique.

ZUSAMMENFASSUNG: Der Zusammenhang zwischen einer 6 Wochen andauernder mütterlichen, depressiven Störung (CES-D) mit den Austauschmustern zwischen Mutter und Kind in der Selbst und Fremdzufriedenheit während einem direkten Spiel wurde bei 132 Dyaden untersucht. Selbst- und interaktive Zufriedenheit (unabhängige beziehungsweise Kreuzkorrelation) wurde zu verschiedenen Zeiten untersucht und

analysiert. Der Blick des Kindes und der Mutter, Ausdrucks- und Stimmaffekt, Berührung und bestimmte Orientierungsverhaltensweisen wurden im Sekundentakt kodiert, indem man Videodokumente mit geteiltem Schirm verwendete. Ein mulitmodales Messsystem des Gesichts- Blickmusters wurde konstruiert, das 9 verschiedene Austauschmuster (Modalitäten) generierte. Mit höheren Werten auf der Depressionsskala wurde die Selbstzufriedenheit bei beiden Partnern in den meisten Paarungen gesenkt. Mit höheren Werten der Depressionsskala waren die interaktiven Zufriedenheitswerte bei beiden erhöht (in manchen Beurteilungen) und gesenkt (in anderen), die sich je nach Partner unterschieden, was zu einem optimierten Mittelwertmodell passte. Bei höheren Werten der Depressionsskala zeigte die interaktive Zufriedenheit die folgenden Muster: 1. Mütter und ihre Kinder hatten eine reziproke Feinfühligkeit der Orientierung; 2. Mütter und Kinder zeigten eine reziproke intermodale Verschobenheit im Bereich der Aufmerksamkeit der Affektkoordination, der Koordination des Senkens des Blicks, aber eine erhöhte affektive Koordination; 3. die Kinder erhöhten, aber die Mütter reduzierten die Berührung mit der Partnerberührung: ein "Kind nähert sich – die Mutter entfernt sich" Berührungsmuster. Die nicht-lineare Analysen zeigten, dass eine veränderte Selbst- und interaktive Zufriedenheit ähnlich waren, sowohl bei den niedrigen (Verweigerung), al auch bei den hohen (Belohnung) Polen der depressiven Symptome bei der Hälfte der Ergebnisse. Diese komplexen, multimodalen Ergebnisse definieren Aspekte der Kommunikationsstörungen, die für die therapeutische Intervention bedeutsam sind.

抄録：生後６週の母親の抑うつ症状(CES-D)と、生後４カ月の母子の対面でのプレイにおける母子の自己および相互交流的応変性パターン self- and interactive contingency patterns との関連が、132 組の母子で調査された。自己および相互交流的応変性（それぞれ自動および遅延相互相関 auto- and lagged cross-correlation）が、多水準の時系列分析によって評価された。 乳児と母親の注視、表情と声の感情、タッチ、および空間的定位 spatial orientation 行動が、分割画面のビデオテープから１秒ごとにコードされ、そして表情と視覚の「かかわりあい engagement」の多様式の尺度が構成され、９の様式の組み合わせ modality pairing が生み出された。CES-D の高い母親では、両パートナーの自己応変性 *self-contingency* が、大部分の様式で低下していた。CES-D の高い母親では、相互交流的応変性 *interactive contingency* の値が、（ある様式では）高いことも、（別の様式では）低いことも両方あった。それはパートナーによって変化し、至適な中間域モデル optimal midrange model と一致した。CES-D の高い母親では、相互交流的応変性は以下のパターンを示した。(1)母親と乳児は、相互の定位への感受性 reciprocal orientational sensitivity をもっていた。(2)母親と乳児には、注意対感情調整の相互の様式間不一致が明らかであり、注視の調整は低下させたが、感情調整は高めた。(3)パートナーのタッチに対するタッチの調整を、乳児は高め、母親は低下させた。すなわち、「乳児が近づき、母親が引き下がる」タッチのパターンだった。非線形解析から、変化した自己および相互交流応変性は、半分の所見において、抑うつ症状の低い（「否認」）方の極と同様に高い（「承認」）方の極でも類似していることが、示された。これらの複雑な多様式の所見は、コミュニケーションの障害のさまざまな側面を定義し、治療的介入への妥当性をもっている。

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This study examines associations of 6-week maternal depressive symptoms with 4-month mother–infant self- and interactive regulation during face-to-face play. Self- and interactive regulation are curiously separate in the research literature. Interactive regulation is the main theme and predicts social and cognitive outcomes (Bakeman, Adamson, Brown, & Eldridge, 1989; Cohn, Campbell, Matias, & Hopkins, 1990; Cohn & Tronick, 1988; Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001; Lewis & Feiring, 1989; Leyendecker, Lamb, Fracasso, Scholmerich, & Larson, 1997; Malatesta, Culver, Rich, & Shepard, 1989; Martin, 1981; Tronick, 1989).

It is essential to integrate both self- and interactive forms of regulation. Each person must both monitor the partner and regulate inner state, and either or both may be misregulated in

each partner (Beebe et al., 2007; Gianino & Tronick, 1988). Rather than locating the source of difficulty in one or the other partner (e.g., infant self-regulatory difficulties or maternal insensitivity), we pry apart the relative contributions of self- and interactive regulation of both partners. If the relative salience of self- versus interactive difficulties varies with different clinical pictures (e.g., depression), therapeutic intervention could be more finely focused.

Although self-regulation (often considered under the more inclusive concept of emotion regulation) is important, we do not know exactly how it is accomplished (Fox, 1994; Thompson, 1994). Its most common definition is the activation or dampening of arousal and the capacity to downregulate negative affect (Kopp, 1989; Stifter, 2002). However, *any* behavioral pattern can be viewed as simultaneously self-regulatory *and* communicative (Overton, 1998).

Predictability of behavior over time, or *contingency*, is our definition of "regulation" (Gottman, 1981; Tronick, 1989). Infants detect contingencies from birth and by 4 months are adept at discriminating *degrees* thereof (Bigelow, 1998; Watson, 1985). Interactive regulation is defined as the predictability of each partner's behavior from that of the other over time (lagged cross-correlation). We adopt the term *interactive contingency*. Self-regulation is defined narrowly as predictability of a person's behavior over time (autocorrelation) in the presence of a particular partner. We adopt the term *self-contingency* to distinguish our meaning of self-regulation from other meanings. Temperament approaches to self-regulation are outside our scope (Fox, 1994; Kopp, 1989).

Infants of depressed mothers are at risk for social, emotional, and cognitive difficulty, whether depression is defined by clinician-based diagnosis or self-report (Gitlin & Pasnau, 1989; Murray & Cooper, 1997). Their affect is less positive, their social and object engagement is impaired, and their attachments are more insecure (e.g., Campbell & Cohn, 1991; Field, 1995; Lyons-Ruth, Repacholi, McCleod, & Silva, 1991; Tronick, 1989; Zlochower & Cohn, 1996). Compared to controls, depressed mothers and their infants spend more time in negative states and match negative states more than positive (Cohn et al., 1990; Field, Healy, Goldstein, & Guthertz, 1990). Infants of depressed mothers have self-regulatory disturbances such as perinatal complications, suggesting difficulty from birth; by 6 months, they have elevated heart rates and cortisol levels (Field, 1995; Murray & Cooper, 1997).

However, the best parsing of social behavior to reveal mechanisms of disturbance remains unclear. Furthermore, microanalytic studies of face-to-face play are inconsistent in documenting altered interactive contingencies in depressed mothers and their infants. Studies differ by type of time-series analysis (time vs. frequency domain), infant age, severity of maternal depression, and socioeconomic status (SES). Using the time domain, Cohn and Tronick's (1989) small, high-risk depressed sample showed lowered interactive contingency in depressed dyads at 6 to 7 months whereas Cohn et al.'s (1990) middle-class depressed sample showed no differences in contingencies at 2 months. Using the frequency domain, Field, Healy, and LeBlanc's (1989) low SES study showed less coherence in depressed dyads at 3 months, but Field et al.'s (1990) low SES study showed no difference in lead/lag relations at 3 months.

THE OPTIMUM MIDRANGE MODEL OF INTERACTIVE REGULATION

Competing hypotheses in the literature have suggested that (a) high interpersonal contingencies are optimal for communication (Chapple, 1970) versus (b) high contingencies index communicative stress (Gottman, 1981). However, Jaffe et al. (2001; Beebe et al., 2000) found that degrees

of vocal rhythm contingency could be excessive as well as insufficient, with the midrange optimum, in predicting attachment from 4-month face-to-face interactions. Vocal contingency was examined in four contexts of mother–infant and stranger–infant, home, and lab. In relation to insecure attachment, high interactive contingency was interpreted as "vigilance," a dyadic effort to create more moment-to-moment predictability in the interaction; and low interactive contingency as inhibition or withdrawal. But in predicting 12-month cognition, *higher* degrees of vocal rhythm contingency were optimal with the *stranger* in the novel lab context. Thus, the "meaning" of degree of contingency, regarding what is optimal for development, was highly sensitive to context: partner, site, and developmental function (see also Cohn & Elmore, 1988).

Other research has converged on an optimum "midrange model" of mother–infant interactive contingency. In predicting 1-year attachment from 3- and 9-month maternal measures, Lewis and Feiring (1989) found that 3-month secure infants showed midrange sociability and object play, and mothers of secure infants midrange responsiveness. Measuring maternal (but not infant) facial contingency, Malatesta et al. (1989) found that high maternal contingency predicted avoidant attachment whereas midrange maternal contingency predicted secure attachment. Sander (1995) reported that relatively more "loosely coupled" (midrange) mother–infant dyads were more resilient whereas in more tightly coupled dyads, any disruption may shatter the system. Roe, Roe, Drivas, and Bronstein (1990) found that only moderately talkative mothers both initiated vocalizations and allowed their infants to do the same; these infants vocalized preferentially to their mothers (vs. strangers), and at 3 and 5 years, exhibited higher cognitive scores. Across 4, 8, and 12 months, Leyendecker et al. (1997) found that secure dyads showed midrange degrees of contingency whereas insecure dyads received higher or lower scores. Beebe et al. (in press), analyzing attention, affect, spatial orientation, and touch, found that insecurity was predicted by 4-month mother and infant self- and interactive contingencies that were heightened (in some modalities) and lowered (in others). Hane, Feldstein, and Dernetz (2003) found that midrange vocal coordination was related to higher maternal sensitivity at 4 months. Beebe et al. (2007) found that 6-week self-criticism was associated at 4 months with heightened maternal interactive contingencies (in some modalities) and lowered (in others); but self-contingency was lowered.

Distinctions between high-intensity, overstimulating mothers and detached, underinvolved mothers are similar to the descriptions of subtypes of depressed mothers as "intrusive" versus "withdrawn" (Cohn et al., 1990; Cohn & Tronick, 1989; Field et al., 1990). Although these studies have addressed degrees of interactive contingency, none have used self-contingency (autocorrelation) as a variable in its own right; instead, it has been statistically controlled and removed (see Gottman, 1981). In research on adult conversation, Warner (1992) was unusual in the integrating of "within-actor" and "between-partner" contingencies.

APPROACH OF THE STUDY

In the current study, we investigate whether specific modalities of the face-to-face exchange may differ in patterns of self- and interactive contingency, defining different aspects of disturbance. Consistent with the literature, we also investigate associations of maternal depression with qualitative features of behavior, such as incidence of maternal intrusive touch. We constructed a multimodal measure of facial–visual "engagement" (Beebe & Gerstman, 1980), consistent with the literature (also see "monadic phases" of Tronick, Als, & Brazelton, 1980). But we also

analyzed modalities separately (see Weinberg & Tronick, 1994), through ordinalized behavioral scales of (a) attention (gaze on/off partner's face), (b) affect (facial and vocal affect), (c) touch, and (d) spatial orientation. Such specificity may yield more information and may be more clinically useful: It is easier to observe specific modalities than a constructed variable.

Mother and infant gaze and facial affect are central modalities of face-to-face exchange (Stern, 1971; Tronick, 1989). Infant vocal affect is an important form of infant communication, particularly vocal distress (Mumme, Fernald, & Herrera, 1996). Infant touch is important in infant self-regulation and self-soothing (Tronick, 1989). Maternal touch is a central, but less examined, modality and was examined in relation to infant measures of vocal affect, touch, and engagement (see Malphurs, Raag, Field, Pickens & Pelaez-Nogueras, 1996; Stepakoff, Beebe, & Jaffe, 2000, 2008). We explored maternal spatial orientation (upright, forward, loom) in relation to infant head orientation (Beebe & Stern, 1977; Demetriades, 2003; Kushnick, 2002; Weinberg & Tronick, 1998). Wherever possible, we attempted to pair the same modality for mother and infant: gaze, facial affect, engagement, touch, and orientation; however, we also examined infant vocal affect in relation to mother facial affect as a second way of exploring the infant's emotional response to the mother's face. We explored one pattern *within* the infant, infant touch, and infant vocal affect, following Tronick's (1989) hypothesis that touch has a self-comforting function, and investigating whether maternal depression affects the likelihood that infant touch modulates infant vocal distress.

HYPOTHESES

Building on Jaffe et al. (2001), where both heightened and lowered interactive contingencies were associated with insecure attachment, and midrange values with secure attachment, we hypothesize that maternal depression biases the mother–infant communication system towards *both* heightened self- and interactive contingency (in some modalities) and lowered (in others). We also explore whether maternal depression is associated with differences in qualitative features of mother and infant behavior (e.g., intrusive maternal touch).

Because low scores of maternal depression may be ambiguous (Shedler, Mayman, & Manis, 1994), we use nonlinear analyses (using depression as a quadratic measure) to explore whether contingency patterns where depression scores move towards the low pole may look similar to contingency patterns where depression scores move towards the high pole.

METHOD

Participants

Recruitment. Within 24 hr of delivering a healthy, full-term, singleton infant without major complications, 152 primiparous mothers were recruited from Columbia University Medical Center for a study of infant social development (1992–1998).[1] Participants were 18 years or older, married (or living with partner), with a home telephone. At 6 weeks, 152 mothers were telephoned and given the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). At 4 months, 132 mothers and infants were videotaped in the lab. No differences were found in ethnicity, education, or infant gender between the 132 participants and the 152 recruited.

[1]This dataset is entirely different from that reported in Jaffe et al. (2001).

Demographic Description. Mothers were 53.0% White, 28.0% Hispanic, 17.5% Black, and 1.5% Asian and were well-educated (3.8% without high-school diploma, 8.3% without college, 28.8% some college, 59.1% college degree or more). Mean age of the participants was 29 years (*SD* 6.5, range = 18–45). Of 132 infants, 58 were female.

Procedure

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

Measurement of Maternal Depressive Symptoms. The CES-D (Radloff, 1977) measures self-reported, current nonspecific distress, "depressive symptoms," not clinically diagnosed depression (Campbell & Cohn, 1991). A score of 16+ at 6 weeks defined a "*hi-CES-D*" group ($n = 34$, 25.8% of the sample; CES-D mean = 24.1, $SD = 6.8$, range = 16–41). Controls ($n = 98$) had CES-D values of 0 to 15 (mean = 8.28, $SD = 3.85$, range = 0–15).[2] We used 6-week (vs. 4-month) CES-D[3] to see whether depressive symptoms at this early stage affect the dyad $2\frac{1}{2}$ months later; 6-week and 4-month CES-D scores were correlated, $r = .47$ ($p < .01$), consistent with Beeghly et al. (2002).

Behavioral Coding. The first $2\frac{1}{2}$ 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 CES-D status, using Tronick and Weinberg (1990) timing rules. Behavioral codes were used to create ordinalized scales for data analysis (required by time-series techniques). Definitions of behavioral scales follow (for details, see Appendices A, B, and C posted on our Web site: http://nyspi.org/Communication_Sciences/index.html). Categories were lumped (indicated by /) when necessary to avoid small frequencies; Gaze: on-off partner's face; for infant, gaze off was further divided into gaze at object versus off. Mother facial affect: mock surprise, smile 3, smile 2, smile 1, "oh" face, positive attention, neutral, "woe" face, negative face (frown, grimace, compressed lips). Mother spatial orientation: upright, forward, loom.

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[2]Preliminary analyses explored CES-D at 6 weeks and at 4 months, as continuous and categorical (16+) variables. We chose 6-week CES-D to see if maternal depressive symptoms at this early stage might affect the dyad almost 2 months later. The group distribution yielded 6% CES-D scores of 0–2, 68.1% scores of 3–15, 10.6% scores of 16–20, 9.9% scores of 21–30, and 5.3% scores of 31–41. Six-week symptoms (16+) were higher than those at 4 months, and preliminary analyses showed 6-week CES-D to be more discriminating, in mother and infant facial affect and gaze regression models. We chose categorical analyses because 6-week CES-D 16+ is a widely accepted clinical cut-off. Furthermore, in preliminary gaze and facial affect regression models, categorical analyses were significant whereas continuous ones were not. A three-category CES-D variable comparing low scores (0, 1, 2: $n = 8$, 6.1% of sample), controls (4–15) and depressed (16+) was considered. It yielded no differences for the low-scoring group versus controls, in exploratory gaze and facial affect regression analyses. (The low-scoring group had inadequate power.)

[3]Missing values for 6-week CES-D ($n = 32$ of 132) were estimated from 8-week CES-D values ($n = 27$) available on a small subset assessed at 8 rather than 6 weeks, or from 4-month CES-D values ($n = 5$) corrected by the 6-week group mean, using regression analyses to impute missing scores.

Infant facial affect: high positive, low positive, interest/neutral, mild negative (frown, grimace), negative (pre-cry, cry-face). Infant touch: none, 1, or 2+ of the following behaviors within 1 s: touch/suck own skin, touch mother, touch object (Hentel, Beebe, & Jaffe, 2000). Infant vocal affect: positive/neutral, none, fuss/whimper, angry protest/cry. Infant head orientation: en face, en face + head down, 30–60 avert, 30–60 avert + head down, 60–90 avert, arch. A dyadic code, "chase and dodge," was defined as a minimum 2-s sequence in which infant averts head 30 degrees or more from vis-á-vis and mother moves head or body in the direction of the infant's movement (Kushnick, 2002).

Mother touch details 21 types, location on infant's body, and intensity (mild/intense) (Stepakoff et al., 2000, 2008), ordinalized from high to low: affectionate (e.g., stroke, kiss), static (e.g., hold, provide finger for infant to hold), playful (e.g., tap, tickle), none, caregive, jiggle/bounce, infant-directed oral touch, object-mediated, centripetal (e.g., touch body center: face, body, head), rough (e.g., scratch, push, pinch), high intensity/intrusive. Codes "affectionate" through "jiggle/bounce" occur in locations of hands, arms, feet, legs; thereafter, touch may occur in locations of infant face, head, or central body.

Multimodal engagement scales were constructed. Infant engagement was ordinalized from a high of "high positive engagement" to a low of "cry." Mother engagement was ordinalized from "mock surprise" to "neutral/negative off" (Beebe & Gerstman, 1980).

Reliability estimates of ordinalized scales were assessed in 30 randomly selected dyads (in three waves to prevent coder "drift"). The mean kappas per variable were for infants: gaze .80, facial affect .78, vocal affect .89, touch .75, and head orientation .71; for mothers: gaze .83, facial affect .68, touch[4] .90, spatial orientation .89; dyadic maternal "chase" and infant "dodge" .89. Mother facial affect (9 degrees) was difficult to code. Using ordinalized scales, eight mother–infant "modality pairings," and a ninth *intrapersonal* infant pairing, were generated for data analysis: (a) infant gaze–mother gaze, (b) infant facial affect–mother facial affect, (c) infant vocal affect–mother facial affect, (d) infant engagement–mother engagement, (e) infant engagement–mother touch, (f) infant vocal affect–mother touch, (g) infant touch–mother touch, (h) infant head orientation–mother spatial orientation, and (i) *infant* touch–*infant* vocal affect.

Data Analysis

Analyses of Qualitative Features of Behavior. One goal of the study was to investigate associations of 6-week CES-D with qualitative features of 4-month behavior, tested as means of the ordinalized behavioral scales, as well as rates of specific "behavioral extremes." Although main effects of the multilevel models could be interpreted for associations with means of behavioral scales, we chose to test for effects separately, without controlling for the various other variables in our models, which is more comparable to the literature. For 4-month qualitative features of behaviors (scale means and rates of behavioral extremes), we used correlations and independent samples *t* tests, examining CES-D continuously and categorically (16+).

The "behavioral extremes" approach followed that of Lyons-Ruth, Bronfman, and Parsons (1999), Tomlinson, Cooper, and Murray (2005), and our previous work (Beebe et al., in press). For example, the mean of the ordinalized maternal touch scale includes the full range of maternal

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

touch behaviors coded whereas the behavioral extreme of the low end of this scale, intrusive touch, identifies a specific clinically meaningful behavior. The precise ways that we defined the behaviors in question were critical in our previous work. In our behavioral extremes approach, we may investigate whether associations with 6-week CES-D can be found in (a) the mere existence of a particular 4-month behavior considered clinically relevant (i.e., maternal intrusive touch), (b) the mean percentage of time per individual that it was used, or (c) its excessive use ($\geq$20% time). Analyses were tailored to each behavior, as appropriate to the distributions (Many were skewed.)

Self- and Interactive Contingency. The second goal of the study was to investigate associations of 6-week CES-D with 4-month self- and interactive contingency. Modeling the complexity of real-time interactions remains difficult. Whereas traditional time-series approaches are 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" (individual differences) and "fixed" (common model) effects on patterns of self- and interactive behavior over 150 s.[6] The models examined nine 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, Chen, Hamgiami, Gordon, & McArdle, 2000; Goldstein, Healy, & Rasbash, 1994; Littell et al., 1996; for details of statistical models, see Chen & 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 across the group (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. Typically, the prior 3 s sufficed to account for

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[5]Multilevel models are designed to address patterns over time (here, the course of behavior second-by-second). They have more power than traditional time-series techniques, take into account error structures, and estimate individual effects with empirical Bayesian (maximum likelihood) techniques (rather than Ordinary Least Squares), which take into account prior distributions (Singer, 1998). 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: (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 depression, (c) control variables and their conditional effects can be included as necessary, (d) nonlinear relations can be examined in the same analyses, and (e) more appropriate statistical model assumptions are made (see Beebe et al., 2007).

[6]A "random effect" is the term used for identifying the differences in a variable (function, or association) among study participants. These always include variation in the mean and 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, they include between-dyad variation in the autoregressive 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.

these lagged effects on the subsequent behavior.[7] Estimated coefficients for effects of these lagged variables on current behavior over the subsequent 147 s of interaction indicate the level of self- or interactive contingency: The larger the coefficient, the stronger the contingency. Each subsequent analysis included both self- and interactive 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 CES-D, 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 facial affect) considered all demographic variables (maternal ethnicity, education and age, and infant gender), effects of lagged variables as described earlier, 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 participants. Therefore, when testing the effects of CES-D, any differences in the magnitude of these estimated coefficients in the fixed-effects model reflect influences of CES-D on self- and interactive contingency. Because our goal was an examination of the effects of CES-D on self- and interactive contingency, we post on our Web site (noted earlier, Appendix D) the "basic model" tables of self- and interactive contingency (three for each of the nine modality pairings, a total of 27 tables). Variables in the "basic" multilevel model were added in the following steps after the intercept of the dependent variable: (1) self and partner lagged variables, (2) demographic variables, (3) conditional effects between demographic variables, and (4) conditional effects of demographic variables with lagged self- and lagged partner behavior. Prior basic across-group analyses showed positive signs for self- and interactive contingency in all pairings except mother spatial orientation–infant head orientation [The negative sign indicated that as infants moved from en face (highest code) towards arch (lowest code), mothers moved from loom (lowest code) towards upright (highest code); and vice versa (Beebe et al., 2006).]

Following each basic model, a conditional linear change model examined the effect of 6-week CES-D (16+) on each 4-month behavioral variable, followed by interactions of CES-D with self- and interactive contingency. Demographic variables significant in the basic model were controlled in all subsequent analyses. Any main or interaction effects of demographic variables are reserved for a future report. We also tested nonlinear effects of CES-D, examining interactions between CES-D scores (as a quadratic term) and self- and interactive contingency. In these nonlinear analyses, CES-D was used as a continuous variable, centered by its mean. Each model included a chi-square test of improvement of fit to the data. Standardized regression coefficients are presented in tables of nonlinear analyses. Type I error was set at $p < .05$ for each model of the nine modality pairings; all tests were two-tailed. With 132 dyads $\times$ 150 s = 19,800 s per partner, per communication modality, we had ample power to detect effects.

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

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[7]Across modality pairings, mother was significant at two to three lags (s); longer lags were not significant. Significant infant lags varied: for self-contingency, two lags (touch), three (face, gaze), and four (vocal affect); for interactive contingency, three (Mother face → Infant vocal affect), five (Mother facial affect → Infant facial affect), and six (Mother gaze → Infant gaze). Although some modality pairings showed lags longer than 3 s, the amount of variance accounted for was very small. No more than three lags were used in any weighted mean lag to maintain consistent sample size.

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

RESULTS

We first present descriptive information on the 6-week CES-D scale, followed by univariate tests of associations between CES-D and qualitative features of behaviors [means of the behavioral scales (facial affect, etc.) and rates of behavioral extremes]. Associations of 6-week CES-D with 4-month self- and interactive contingency are then addressed with linear and nonlinear regression equations. Linear equations analyze effects of depressive symptoms categorically (presence/absence), and results are interpreted as characterizing the hi-CES-D (16+) group versus controls; nonlinear equations analyze effects of depression as a continuous variable, and results are interpreted as characterizing the high and low poles of CES-D scores, compared to dyads where mothers scored midrange. Consistent with prior literature, we first describe the picture of *high depressive symptoms*, noting findings associated with higher CES-D *whether linear or nonlinear* (right-hand side of graphed effects).We then describe nonlinear effects to evaluate whether movement away from the center towards high and low CES-D poles was associated with similar increases (or decreases) in contingency.

Description of 6-Week Depressive Symptoms

The 6-week CES-D distribution was skewed (skewness 1.20 ($SE = .21$) with a mean of 12.34 ($SD = 8.41$), median 10.46, and mode 9.00 (The histogram is posted on our Web site, Appendix E). Representation of participants at the high and low ends is adequate for our conclusions, but there is more discrimination at the high end. Eight participants endorsed zero, one, or two CES-D items. Assessing 6-week CES-D as a continuous variable, there were no results for maternal ethnicity and infant gender, but lower education (grade school, high school, some college) was associated with higher CES-D scores than was higher education (college degree, graduate school) ($t = 2.835$, $p < .005$).

Are Depressive Symptoms Associated With Qualitative Behavioral Features?

Significant associations of CES-D with qualitative behavioral features follow. Appendices F1 and F2 (posted on our Web site) present the full results of testing the means of the behavioral scales and the rates of behavioral extremes, respectively.

Mother and Infant Gaze. Using mean number of seconds (of 150 s total) gaze on, mothers with higher CES-D scores spent more time at 4 months looking at their infants' faces (mean = 135.03 s, $SD = 10.1$) than control mothers (mean = 129.3 s, $SD = 14.4$), tested continuously ($r = .207$, $p = .017$), and categorically ($t = 2.629$, $df = 84.6$, $p = .010$). Reciprocally, infants of mothers with higher CES-D scores spent more time looking at mothers' faces (mean = 81.2 s, $SD = 36.2$) than

control infants (mean = 60.9 s, $SD = 40.6$), tested categorically ($t = 2.570$, $df = 129$, $p = .011$; not significant tested continuously).

Mother Touch. Using the mean of the ordinalized maternal touch scale (from "affectionate" to "intrusive"), mothers with higher 6-week CES-D had lower mean maternal touch, tested continuously ($r = -.187$, $p < .05$; not significant tested categorically). Tested as a behavioral extreme, mothers with higher CES-D showed greater percent-time in intrusive touch, tested continuously ($r = .212$, $p = .02$; not significant tested categorically). To illustrate, mothers with CES-D 16+ showed twice the percent time (mean = 10.96, $SD = 20.98$) in intrusive touch as control mothers (mean = 5.73, $SD = 13.77$).

Mother Engagement. Using the mean of the ordinalized facial–visual engagement scale, tested categorically, hi-CES-D mothers had higher engagement levels (mean =51.2, $SD = 6.6$, corresponding to "neutral face") than did controls [mean = 48.1, $SD = 7.2$, between "neutral face" (=50) and "woe face" (=45)] ($t = 2.156$, $df = 128$, $p = .033$; tested continuously, it was not significant]. This finding indicates that control mothers showed more facial empathy for infant distress through "woe face."

Infant Head Orientation. Using the mean of the ordinalized infant head orientation scale [from enface (Code 6) to arch (Code 1)], tested categorically, infants of hi-CESD mothers had higher head orientation (mean = 5.39, $SD = .58$, between en face and head down) than did infants of controls (mean = 5.11, $SD = .77$, corresponding to head down) ($t = 2.27$, $df = 77.25$, $p = .026$; not significant tested continuously). Infants of depressed mothers spent more time specifically in the en face head orientation, testing percent-time en face categorically by *t* test and continuously by Mann–Whitney *U*, more appropriate to the highly skewed distribution ($U = 1259$, $p = .041$). To illustrate, half the control infants spent 70% time or more en face; in contrast, half the infants of hi-CES-D mothers spent 80% time or more en face. Thus, somewhat more time venturing away from en face is characteristic of infants of control mothers.

Are Depressive Symptoms Associated With Altered Self- and Interactive Contingency?

Significant standardized estimates (β) of the linear and nonlinear effects of 6-week CES-D on 4-month self- and interactive contingency for the nine modality pairings are presented in Tables 1 and 2, respectively, and illustrated in Figure 1. Negative signs indicate lowered contingency estimates with higher CES-D. Nonlinear findings are interpreted here only for the *high end* of *increasing* CES-D scores (Those for the low end are discussed later.) In Figure 1, arrows which curve from infant to mother represent mother interactive contingency (vice versa for infant); arrows which 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 predicted maternal behavior in the current moment: Mother coordinates with infant (vice versa for "M → I"). *Broken* arrows represent findings where depressive symptoms generated lowered contingency values; *unbroken* arrows represent heightened contingency values (compared to controls for linear equations and compared to dyads where mothers scored midrange for nonlinear equations, respectively). Absence of arrows represents *no effects of CES-D*. Brackets in the margins of Figure 1 demarcate five domains: attention (Pairing 1), affect (Pairings 2, 3, 4),

TABLE 1. *Maternal 6-Week Depressive Symptoms (CES-D 16+) and 4-Month Self- and Interactive Contingency: Linear Effects*

		INFANT			MOTHER	
		β	*SE β*		*β*	*SE β*
Pattern (1)		Infant Gaze			Mother Gaze	
	CESD	.398*	.165	CESD	.154	.129
	I→I/CESD	**−.227***	**.109**	M→M/CESD	.293	.197
	M→I/CESD	**−.165***	**.083**	**I→M/CESD**	**−.363***	**.152**
Pattern (2)		Infant Facial Affect			Mother Facial Affect	
	CESD	.143	.401	CESD	.248	.353
	I→I/CESD	.006	.015	**M→M/CESD**	**−.047****	**.016**
	M→I/CESD	.017	.019	**I→M/CESD**	**.039****	**.015**
Pattern (3)		Infant Vocal Affect			Mother Facial Affect	
	CESD	−.009	.063	CESD	.339	.298
	I→I/CESD	.012	.015	M→M/CESD	−.032†	.018
	M→I/CESD	.0001	.001	**I→M/CESD**	**.581***	**.285**
Pattern (4)		Infant Engagement			Mother Engagement	
	CESD	.218	.170	CESD	.105	.077
	I→I/CESD	**−.033***	**.014**	M→M/CESD	−.028	.020
	M→I/CESD	−.017	.036	I→M/CESD	.005	.009
Pattern (5)		Infant Engagement			Mother Touch	
	CESD	.236	.166	CESD	−.065	.074
	I→I/CESD	**−.032***	**.014**	**M→M/CESD**	**−.064*****	**.012**
	M→I/CESD	−.038†	.023	I→M/CESD	−.008	.008
Pattern (6)		Infant Vocal Affect			Mother Touch	
	CESD	.001	.017	CESD	−.061	.078
	I→I/CESD	−.021	.016	**M→M/CESD**	**−.055*****	**.012**
	M→I/CESD	−.003	.003	I→M/CESD	−.090	.058
Pattern (7)		Infant Touch			Mother Touch	
	CESD	.006	.012	CESD	−.075	.079
	I→I/CESD	−.013	.011	**M→M/CESD**	**−.071*****	**.012**
	M→I/CESD	**.006***	**.003**	I→M/CESD	−.054	.062
Pattern (8)		Infant Head Orientation			Mother Spatial Orientation	
	CESD	.096	.051	CESD	−.014	.029
	I→I/CESD	**−.046****	**.015**	**M→M/CESD**	**−.059*****	**.013**
	M→I/CESD	−.006	.033	**I→MCESD**	**−.018****	**.006**

(Continued)

TABLE 1. *Continued*

Pattern (9)		INFANT Infant Vocal Affect			INFANT Infant Touch	
	CESD	.004	.018	CESD	.005	.013
	I→I/CESD	−.003	.016	I→I/CESD	−.007	.011
	I→I/CESD	−.021	.014	I→I/CESD	−.008	.014

Note. 1. Estimated fixed effects of maternal depression and interaction with M→M, I→M (or I→I, M →I) based on the "basic models," controlling for demographic variables and infant gender.
2. CESD = main effect of CESD on the mean of the behavioral scale; I→I/CESD = effect of CESD on infant self-contingency; M→I/CESD = effect of CESD on infant interactive contingency.
3. M→I = Mother behavior (lagged) predicts Infant behavior (current second); I→M = Infant behavior (lagged) predicts Mother behavior (current second).
4. All parameter entries are maximum likelihood estimates fitted using SAS PROC MIXED.
5 Maternal depression at 6 weeks: CESD=16+ coded 1; CESD<16 coded 0.
6. Negative signs indicate lower mean values of behavioral scales (main effects) or lower estimates of self- and interactive contingency.
7. $^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

mother touch in relation to infant behavior (Pairings 5, 6, 7), orientation (Pairing 8), and infant intrapersonal vocal affect and touch (Pairing 9).

The Picture of Higher CES-D

(1) Infant Gaze–Mother Gaze

Self-Contingency. Infants of hi-CES-D (16+) mothers showed lowered gaze self-contingency compared to infants of control mothers (CES-D $\leq$ 15) (Table 1, I $\rightarrow$ I/CESD $\beta = -.227$, $p < .05$). Likewise, with higher CES-D, maternal gaze self-contingency was lowered (Table 2, M $\rightarrow$ M/CESD^2 $\beta = -.169$, $p < .01$) compared to mothers scoring midrange (see Figure 1).

Interactive Contingency. Compared to controls, hi-CES-D mothers and their infants both lowered their gaze coordination with the others' shifts of gaze on/off the partner's face (Table 1).

(2) Infant Facial Affect–Mother Facial Affect

Self-Contingency. With hi-CES-D, mother facial affect self-contingency was lowered compared to control mothers (Table 1).

Interactive Contingency. With higher CES-D, mothers heightened their facial coordination with infant face compared to controls (Table 1) and to mothers scoring midrange (Table 2).

(3) Infant Vocal Affect–Mother Facial Affect

Self-Contingency. With higher maternal CES-D, infant vocal affect self-contingency was lowered compared to infants of mothers scoring midrange (Table 2).

TABLE 2. *Maternal 6-Week Depressive Symptoms (CES-D) and 4-Month Self- and Interactive Contingency: Nonlinear Effects*

		INFANT			MOTHER	
		β	*SE* β		β	*SE* β
Pattern (1)		Infant Gaze			Mother Gaze	
	$CESD^2$	.008	.054	$CESD^2$	−.057	.043
	I→I	3.570***	.062	M→M	2.725***	.097
	I→I/$CESD^2$	.022	.039	**M→M/$CESD^2$**	**−.169****	**.058**
	M→I	.494***	.140	I→M	.568***	.084
	M→I/$CESD^2$	.104	.090	I→M/$CESD^2$	.023	.051
Pattern (2)		Infant Facial Affect			Mother Facial Affect	
	$CESD^2$	−.060	.131	$CESD^2$	.038	.112
	I→I	.651***	.010	M→M	.562***	.009
	I→I/$CESD^2$	.003	.005	M→M/$CESD^2$	−.008	.005
	M→I	.046***	.010	I→M	.116***	.009
	M→I/$CESD^2$	.003	.006	**I→M/$CESD^2$**	**.017****	**.005**
Pattern (3)		Infant Vocal Affect			Mother Facial Affect	
	$CESD^2$	−.053**	.020	$CESD^2$	.029	.093
	I→I	.662***	.010	M→M	.632***	.008
	I→I/$CESD^2$	−.017***	.005	M→M/$CESD^2$	−.005	.005
	M→I	.001*	.001	I→M	1.213***	.160
	M→I/$CESD^2$	**.001****	**.0003**	I→M/CESD2	.139	.097
Pattern (4)		Infant Engagement			Mother Engagement	
	$CESD^2$	.069	.054	$CESD^2$	−.023	.024
	I→I	.688***	.008	M→M	.484***	.012
	I→I/$CESD^2$	**−.009***	**.005**	**M→M/$CESD^2$**	**−.014***	**.006**
	M→I	.041*	.020	I→M	.056***	.006
	M→I/$CESD^2$	**.024***	**.012**	**I→M/$CESD^2$**	**.007***	**.003**
Pattern (5)		Infant Engagement			Mother Touch	
	$CESD^2$	.079	.053	$CESD^2$	−.018	.024
	I→I	.698***	.008	M→M	.738***	.007
	I→I/$CESD^2$	−.006	.005	M→M/$CESD^2$	.001	.004
	M→I	.009	.013	I→M	.006	.005
	M→I/$CESD^2$	.004	.007	I→M/$CESD^2$	−.002	.003
Pattern (6)		Infant Vocal Affect			Mother Touch	
	$CESD^2$	.009	.005	$CESD^2$	−.022	.025
	I→I	.699***	.013	M→M	.738***	.007
	I→I/$CESD^2$	**−.013****	**.005**	M→M/$CESD^2$	−.00064	.004
	M→I	.001	.002	I→M	.082**	.032
	M→I/$CESD^2$	.001	.001	I→M/$CESD^2$	−.012	.019

(Continued)

TABLE 2. *Continued*

		INFANT			MOTHER	
		β	*SE* β		β	*SE* β
Pattern (7)		Infant Touch			Mother Touch	
	$CESD^2$	.004	.004	$CESD^2$	−.017	.027
	I→I	.707***	.006	M→M	.730***	.007
	I→I/$CESD^2$	.006	.004	M→M/$CESD^2$	.002	.004
	M→I	.001	.002	I→M	.194***	.035
	M→I/$CESD^2$	**−.002***	**.001**	**I→M/$CESD^2$**	**−.114*****	**.022**
Pattern (8)		Infant Head			Mother Spatial	
	$CESD^2$	.037	.047	$CESD^2$	.011	.301
	I→I	.642***	<.001	M→M	.703***	<.001
	I→I/$CESD^2$	−.001	.864	**M→M/$CESD^2$**	**.022*****	**<.001**
	M→I	−.007	.723	I→M	−.005	.144
	M→I/$CESD^2$	.014	.237	I→M/$CESD^2$	−.006	.018
	M→I/$CESD^2$	.013	.010	I→M/$CESD^2$	−.004	.008
		INFANT			INFANT	
Pattern (9)		Infant Vocal Affect			Infant Touch	
	$CESD^2$	.012	.005	$CESD^2$	.003	.004
	IVoc→IVoc	.694***	.012	ITch→ITch	.774***	.006
	IVoc→IVoc/$CESD^2$	**−.016****	**.005**	ITch→ITch/$CESD^2$	.005	.004
	ITch→IVoc	−.004	.012	IVoc→→ITch	.025***	.008
	Itch→IVoc/$CESD^2$	**.001***	**.005**	IVoc→ITch/$CESD^2$	.001	.005

Note. 1. Standardized estimated fixed nonlinear (NL) effects (β) of maternal depression and interaction with M→M, I→M (or I→I, M→I) based on the "basic models," controlling for demographic variables and infant gender; *SE* β = Standard Error of the Beta.
2. CESD = maternal depression at 6 weeks; the scale was centered by its mean.
3. I→M = Infant behavior (lagged) predicts Mother behavior (current second); M→I = Mother behavior (lagged) predicts Infant behavior (current second).
4. $CESD^2$ = NL main effect of CESD on behavioral scales; I →I/$CESD^2$ = NL effect of CESD on infant self-contingency; M → I/$CESD^2$ = NL effect of CESD on infant interactive contingency.
5. All parameter entries are maximum likelihood estimates fitted using CESD GLIMMIX Macro.
6. Both depression as a linear effect, and its linear conditional effect on self- and interactive contingency, were included in all NL models but are not presented here. However we do include estimates of self-and interactive contingency to facilitate interpretation of NL conditional effects of $CESD^2$ on these estimates.
7. Since only nonlinear results are of interest in this table, significant nonlinear results are bolded.
8. Negative signs indicate lower mean values of behavioral scales, or lower estimates of self- and interactive contingency.
9. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Interactive Contingency. Hi-CES-D mothers heightened their facial coordination with infant vocal affect compared to control mothers (Table 1). Infants of higher CES-D mothers reciprocally heightened their vocal affect coordination with maternal facial affect compared to infants of mothers scoring midrange (Table 2). This nonlinear effect was extremely subtle.

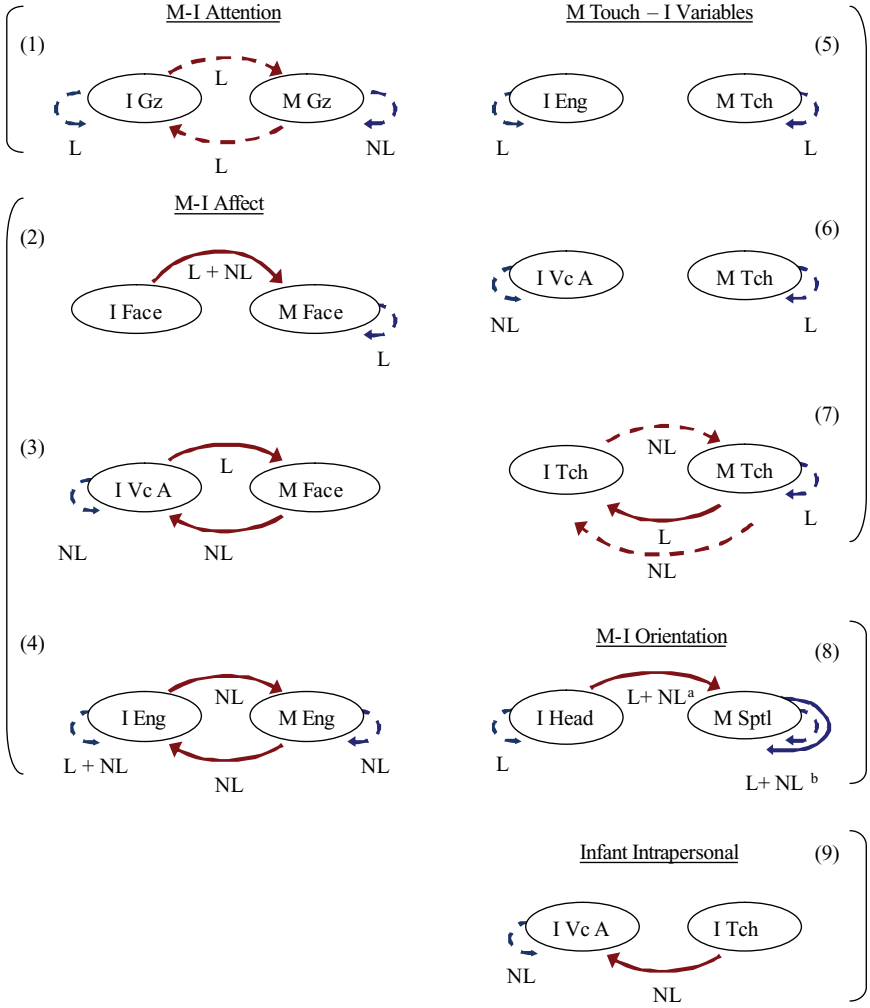

FIGURE 1. Maternal 6-week CES-D and altered self- and interactive contingency.
1. Summary of all linear (**L**) (Table 1) and nonlinear (**NL**) (Table 2) findings; NL findings for high end of depression only; **L + NL** indicates effects that are both linear and nonlinear; Gz = Gaze, Face = Facial Affect, Vc A = Vocal Affect, Eng = Engagement, Tch = Touch, I Head = Infant Head Orientation, M Sptl = Mother Spatial Orientation.
2. I → M = Infant behavior (lagged) predicts Mother behavior (current second) (i.e., "Mother coordinates with Infant"); M → I = Mother behavior (lagged) predicts Infant behavior (current second) (i.e., "Infant coordinates with Mother").
3. ⇢ If mother is depressed (CES-D 16+) vs. non-depressed, contingency is lower
4. ➡ If mother is depressed (CES-D 16+) vs. non-depressed, contingency is higher
5. If **NO ARROW**: No significant conditional effect of maternal depression on contingency.
6. (1)–(9) indicate the 9 modality pairings examined, grouped by domains: attention (Pattern 1), affect (Patterns 2–4), mother touch (Patterns 5–7), spatial orientation (Pattern 8), and infant intrapersonal (Pattern 9).
[a]Across the group, there was a significant negative association of lagged I Head → M Spatial. That is, as infants moved from the head-orientation position of en face (highest code) towards 90-degree aversion or arch (lowest code), mothers moved from loom (lowest code) to forward or upright (highest code). Reciprocally, as infants moved from 90-degree aversion or arch towards en face, mothers moved from upright towards forward or loom. The depressed (vs. nondepressed) group showed a significant increase in this negative association, and thus an even stronger negative

(4) Infant Engagement–Mother Engagement

Self-Contingency. With higher CES-D, infant engagement self-contingency was lowered compared to infants of control mothers (Table 1) and to infants of mothers scoring midrange (Table 2). Likewise, mother engagement self-contingency was lowered compared to mothers scoring midrange (Table 2).

Interactive Contingency. With higher CES-D, mothers and infants heightened engagement coordination with each other compared to dyads where mothers scored midrange (Table 2).

(5) Infant Engagement–Mother Touch

Self-Contingency. With hi-CES-D, both infant engagement self-contingency was lowered and mother touch self-contingency was lowered compared to controls (Table 1).

Interactive Contingency. No interactive contingency findings.

(6) Infant Vocal Affect–Mother Touch

Self-Contingency. With higher maternal CES-D, infant vocal affect self-contingency was lowered compared to infants of mothers scoring midrange (Table 2), and mother touch self-contingency was lowered compared to control mothers (Table 1).

Interactive Contingency. There were no interactive contingency findings.

(7) Infant Touch–Mother Touch

Self-Contingency. In hi-CES-D mothers (vs. controls), mother touch self-contingency was lowered (Table 1).

Interactive Contingency. Infants of higher CES-D mothers showed opposite signs of heightened linear (Table 1), but lowered nonlinear (Table 2), touch coordination with mother touch. Graphing revealed that the linear relation characterized most infants: Infants of hi-CES-D mothers had higher touch coordination with mother touch. However, at the extreme high pole of CES-D values (where data were sparse) as well as at the extreme low pole, infant coordination was zero. This nonlinear effect was extremely subtle. Higher CES-D mothers showed lowered touch coordination with infant touch compared to mothers scoring midrange (Table 2).

(8) Infant Head Orientation–Mother Spatial Orientation

Self-Contingency. Higher CES-D mothers showed opposite signs of lowered linear (Table 1), but heightened nonlinear (Table 2), spatial self-contingency. Graphing revealed that the linear

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FIGURE 1. correlation. This association is bolded in the figure to show that the association is strengthened in the depressed group.

[b]As noted in the results, there was a significant nonlinear as well as linear effect of CES-D on mother spatial self-contingency. A linear decrease in self-contingency was modified by a nonlinear increase. With increasing depression, mothers tended to have lower contingency, the linear effect; however, as depression increased, the linear decline flattened out, and there was no further decline. Thus, the primary effect is the linear decrease in self-contingency.

relation characterized most mothers: Hi-CES-D mothers had lower spatial self-contingency. A $t \rightarrow t+1$ transition matrix revealed that depressed mothers were less likely to maintain each of the spatial positions (upright, forward, loom). Infants of hi-CES-D mothers (vs. controls) showed lowered head orientation self-contingency (Table 1). An illustrative transition matrix revealed that infants of depressed mothers were more likely to stay in en face, more likely to return to en face from any other head position, and less likely to stay in head positions of en face + head down, 30–60 avert, and 30–60 avert + head down.

Interactive Contingency. Hi-CES-D mothers (vs. controls, Table 1; and vs. midrange CES-D, Table 2) showed a significant increase in the negative association of mother spatial coordination with infant head orientation. Across the group, there was a significant negative association of infant head orientation predicting mother spatial orientation: As infants moved from the head position of en face (highest code) towards arch (lowest code), mothers moved from loom (lowest code) towards upright (highest code), and vice versa. This association is bolded in Figure 1 to show that the negative association is strengthened in the depressed group.

(9) Infant Vocal Affect–Infant Touch

Self-Contingency. With higher maternal CES-D, infant vocal affect self-contingency was lowered compared to infants of mothers scoring midrange (Table 2).

Interactive Contingency. With higher maternal CES-D, the effect of infant touch on infant vocal affect was greater compared to infants of mothers scoring midrange (Table 2). The positive association between touch and vocal affect indicated that more infant touch predicted more positive infant vocal affect, and vice versa. This association was heightened in infants of depressed mothers. This nonlinear effect was extremely subtle.

The Picture of the Low Pole of CES-D: Nonlinear Analyses

Whereas the previous section described the picture of dyads where mothers *endorsed* depressive symptoms at 6 weeks, we now return to the nonlinear analyses (presented earlier, Table 2) to interpret findings *at the low end* of the CES-D scale. Graphs of the nonlinear findings are posted on our Web site in Appendix G (Very subtle nonlinear findings, noted later, were not graphed.) Where significant, these nonlinear analyses show that *alterations in self- and interactive contingency associated with the low pole of CES-D scores were similar to those associated with the high pole* (similar in direction, but not necessarily absolute amount), where both poles are compared to dyads with midrange scores. Half of the findings (15/29) were nonlinear.

(1) Infant Gaze–Mother Gaze

Self-Contingency.

At both high and low poles of CES-D, maternal gaze self-contingency was lowered compared to mothers scoring midrange.

Interactive Contingency. There were no nonlinear findings.

(2) Infant Facial Affect–Mother Facial Affect

Self-Contingency. There were no nonlinear findings.

Interactive Contingency. At both high and low CES-D poles, mothers showed heightened facial coordination with infant facial affect compared to mothers scoring midrange.

(3) Infant Vocal Affect–Mother Facial Affect

Self-Contingency. At both high and low CES-D poles, infant vocal affect self-contingency was lowered compared to infants of mothers scoring midrange.

Interactive Contingency. At both high and low CES-D poles, infants heightened their vocal affect coordination with maternal facial affect compared to infants of mothers scoring midrange. This effect was extremely subtle.

(4) Infant Engagement–Mother Engagement

Self-Contingency. At both high and low CES-D poles, infant and mother engagement self-contingency were lowered compared to midrange dyads. The nonlinear effect for mother self-contingency is more pronounced at the high CES-D end.

Interactive Contingency. At both high and low CES-D poles, mothers and infants heightened engagement coordination with each other compared to dyads where mothers scored midrange.

(5) Infant Engagement–Mother Touch

Self-Contingency. There were no nonlinear findings.

Interactive Contingency. There were no nonlinear findings.

(6) Infant Vocal Affect–Mother Touch

Self-Contingency. At both high and low CES-D poles, infant vocal affect self-contingency was lowered compared to infants of midrange mothers.

Interactive Contingency. There were no nonlinear findings.

(7) Infant Touch–Mother Touch

Self-Contingency. There were no nonlinear findings.

Interactive Contingency. At both high and low poles of CES-D, mothers and infants both showed lowered touch coordination with the other. At the extremes of the high and low poles, infant coordination values were zero. The nonlinear effect for infants was extremely subtle.

(8) Infant Head Orientation–Mother Spatial Orientation

Self-Contingency. A significant positive nonlinear finding for mother spatial self-contingency slightly modified the negative linear relation such that, as CES-D increased, the linear decline flattened out, with no further decline. Thus, this relation was primarily linear.

Interactive Contingency. A significant nonlinear finding of mother spatial orientation coordination with infant head orientation slightly modified the linear relation, but the nonlinear component is so subtle that it is interpreted identically to the linear finding mentioned earlier (see earlier Pairing 8, "The picture of higher CES-D;" and Figure 1, Footnote b).

(9) Infant Vocal Affect–Infant Touch

Self-Contingency. At both high and low CES-D poles, infant vocal affect self-contingency was lowered compared to infants of midrange mothers.

Interactive Contingency. At both high and low CES-D poles, the effect of infant touch on infant vocal affect was greater than that of infants whose mothers scored midrange. This effect was extremely subtle.

Of the 72 equations run, 30 (42%) were significant—a nonrandom pattern of findings.

DISCUSSION

We studied maternal 6-week self-report depressive symptoms rather than clinically diagnosed depression. These symptoms indicate current, but nonspecific, distress such as difficulty sleeping, eating, crying spells, fearfulness, feeling lonely, and feeling like a failure. In a large, diverse community sample, we hoped for a more generalizable sample than in many studies of maternal depression which focus on a specific clinical or demographic subgroup; however, the sample was highly educated, with a high incidence of depressive symptoms (25%) for a community sample (Campbell & Cohn, 1991). Higher CES-D scores were associated with lower education levels.

Predictability over time operationalized the concept of contingency. Infants perceive temporal sequences, contingencies, and degrees thereof, and expect when events will occur (DeCasper & Carstens, 1980; Haith, Hazan, & Goodman, 1988; Watson, 1985). Degree of self-contingency generates expectancies of predictability or stability of one's own behavior. Degree of interactive contingency generates expectancies of how predictably the partner changes in relation to one's own changes, and vice versa, organizing expectancies, metaphorically, of "how I affect you" and "how you affect me."

In previous work, we interpreted high coordination as an effort to create more predictability in the dyad under conditions of novelty, challenge, or threat; we interpreted low coordination as withdrawal or inhibition (Jaffe et al., 2001). Heightened and lowered interactive contingency are translated into the metaphors of "vigilant" and "withdrawn (i.e., inhibited)," respectively. Vigilance for the social signals of the other is an important aspect of social intelligence likely to have been an evolutionary advantage in conditions of uncertainty or threat, and is likely to be accompanied by emotional activation (Ohman, 2002). We conceptualize a partner's lowered interactive coordination as a "withdrawal" or "distancing" from the individual, compromising the

individual's interactive agency by lowering the ability to anticipate the consequences of his or her own actions. Lowered self-contingency is translated into the metaphor of "self-destabilization," a lowered ability to anticipate one's own state. Infant expectancies of different patterns of self- and interactive contingency are one process by which maternal depressive symptoms might be transmitted to the infant and alter the trajectory of development.

The Optimal Midrange Model of Self- and Interactive Regulation

We hypothesized that across the system of both partners and all communication modalities, 6-week maternal depression biases the 4-month communication system towards *both* heightened contingency values (in some modalities) and lowered ones (in others). Findings for *interactive* contingency were consistent with our hypothesis. Thus, interactive contingency can be "excessive" (i.e., vigilant) or "insufficient" (i.e., withdrawn), consistent with Jaffe et al. (2001), who documented that excessive and insufficient degrees of vocal rhythm interactive contingency predicted insecure attachment.

However, self-contingency did not fit our hypothesis. With maternal depression, self-contingency was lowered for mothers and infants. This is an important finding, consistent with Beebe et al. (2007). Lower self-contingency makes it harder for each individual to anticipate one's own and the partner's ongoing behavioral stream. With lower self-contingency, the cues by which one knows oneself are less predictable, and one knows less what to expect of oneself, yielding a decreased sense of coherence over time.

Maternal Depressive Symptoms and Interactive Contingency

Gaze. Hi-CES-D mothers and their infants both showed lowered 4-month coordination with the other's on-off gaze pattern, a form of mutual interactive withdrawal. But each looked at the other more, as if vigilantly watchful. These findings occurred in the context of lower mother and infant gaze self-contingency, making each less predictable to self and partner. *Looking more, but coordinating less* is interpreted as a form of "*noninteractive looking*." Attention to the partner's direction of gaze on and off one's own face is a critical foundation of the face-to-face encounter (Brazelton, Koslowski, & Main, 1974; Tronick, 1989), disturbed in hi-CES-D mothers and their infants.

Increased looking at the partner is an unusual finding, generally inconsistent with the depression literature in which less attending behavior was found (Cohn et al., 1990), particularly in infants of low SES samples (see Field, 1995), who are likely to be different from our well-educated community sample. More looking in both partners may index wariness; longer infant looking may index less competent visual processing (Colombo, Richman, Shaddy, Greenhoot, & Maikranz, 2001). However, the finding of lowered interactive gaze contingencies *is* consistent with the literature.

Face. Despite lowered gaze coordination, hi-CES-D mothers heightened their facial coordination with infant facial/vocal affect, compared to controls, tending to brighten and sober as infants did; however, hi-CES-D mothers showed less "woe-face," an expression of facial empathy for infant distress. Hi-CES-D mothers heightened their facial coordination, but lowered their facial self-contingency, an interactive versus self-contingency imbalance, overly facially coordinated with infants while sacrificing their own facial stability. Infants of hi-CES-D mothers heightened

their vocal affect coordination with maternal facial affect. This was a subtle effect, interpreted with caution.

Facial–Visual Engagement. Hi-CES-D mothers and their infants reciprocally heightened their engagement coordination, a mutual vigilance. This vigilance operated as a "positive feedback" system in which deviations were amplified: Both partners were overly reactive to the other (Weiner, (1948). Mothers may be overly "thrilled" when infants are positive and overly disappointed when infants are negative. But both partners tended to be overly coordinated with the other while sacrificing self-stability.

Hi-CES-D mothers and their infants thus both showed a peculiar intermodal discordance in contingency: lowered contingency of gaze on-off, but heightened contingency of facial/vocal/engagement shifts. Whereas attention and affect usually operate together as a "package" (Beebe & Gerstman, 1980), this split attention/affect coordination is a contradictory, confusing communication pattern.

Touch. Infants of hi-CES-D mothers showed heightened touch coordination with mother touch compared to controls (Infants of very high CES-D mothers no longer showed this effect.) This finding is striking on two counts. First, this pattern was not significant in control dyads: Infants did not coordinate their touch patterns with mother touch, so that control infants were free to use touch independent of mother's touch pattern. Second, hi-CES-D mothers had more intrusive touch, so that their infants were tightly coordinated with a more intrusive form of maternal touch. More intrusive touch in depressed mothers is consistent with other studies (see Field, 1995; Hart, Jones, Field, & Lundy, 1999; Malphurs et al., 1996). Infants' close coordination with maternal intrusive touch may be an effort to manage it. The positive correlation indicates that infants were less likely to use touch as maternal touch patterns became less affectionate, and vice versa. Thus, these infants were not free to use touch as needed, particularly when mothers were intrusive. For control infants, touch was uncoupled from maternal touch, more at infant disposal as needed. Strikingly, hi-CES-D mothers *decreased* their touch coordination with infant touch. Thus, maternal touch was more intrusive and less sensitively coordinated with infant touch patterns. This is an "infant approach–mother avoid" pattern, a form of dyadic conflict in the realm of touch.

Spatial Orientation. Hi-CES-D mothers were more spatially coordination with infant head orientation than were control mothers. As infants oriented away, from en face towards arch, hi-CES-D mothers were more likely to move from loom towards upright; reciprocally, as infants moved from arch towards en face, hi-CES-D mothers were more likely to move from upright to forward or loom. Thus, hi-CES-D mothers were more sensitive to infant head orientation, more likely to draw back as infants moved away, and more likely to move forward as infants reoriented. This maternal spatial orientation "vigilance" is consistent with the hi-CES-D mother's facial "vigilance:" Both findings indicate a greater reactivity to the infant's level of contact. However, it is striking that hi-CES-D mothers coordinated more with infant head orientation, but less with infant direction of visual regard, another peculiar discordance. Infants of hi-CES-D mothers were more likely than were control infants to remain en face, whereas control infants were more free to venture away from en face. Thus, a dyadic orientational sensitivity emerged in hi-CES-D pairs. Infants of hi-CES-D mothers were more likely to remain en face, to look at mother's face, and to closely coordinate with maternal engagement, but less likely to visually

coordinate with mother's gaze on-off, a complex combination of attentional vigilance and avoidance.

Infant Intrapersonal Vocal Affect–Touch. Infants of both hi-CES-D and control mothers showed a positive correlation in the infant intrapersonal pattern of vocal affect–touch. When infants touched more in the previous few seconds, infant vocal affect was more positive in the subsequent second (and vice versa). Thus, more infant touch functioned as a "coping mechanism" associated with less vocal distress. This association was heightened in infants of depressed mothers, suggesting both a compensatory infant attempt to manage vocal distress through touch as well as a greater likelihood of vocal distress when infants touched less. This is a subtle effect, interpreted with caution.

Infant Experience of Touch Patterns in hi-CES-D Dyads. We propose that as infants sense their own close coordination with intrusive maternal touch, whereby they are less likely to touch as mother's touch becomes less affectionate (and vice versa), infants experience a lessened efficacy in ability to regulate their own state: Touch is not as available as needed. Additionally, because mothers lowered their touch coordination with infant touch, infants may experience a decreased agency in their ability to affect maternal touch patterns.

Summarizing the picture of hi-CES-D mothers, the maternal findings of (a) dampened gaze coordination with infant gaze, indicating a lowered monitoring of infant availability for visual engagement; (b) dampened touch coordination with infant touch, in the context of intrusive maternal touch; (c) less facial empathy through "woe face;" (d) more time spent looking at the infant's face; and (e) heightened coordination with infant facial/vocal affect, engagement, and head orientation, together suggest the speculation that these mothers were more self-preoccupied. It is as if they were overusing the infant's affective state to regulate their own, perhaps using the infant's face to see if they were loved. This maternal pattern is characterized as "emotional hovering" and spatially overreactive, but also as relatively oblivious to infant visual availability and touch. The self-contingency of the mothers' own behavioral rhythms was destabilized in gaze, facial affect, facial–visual engagement, and touch, likely yielding an experience of lowered self-coherence within the face-to-face interaction.

Summarizing the picture of infants of hi-CES-D mothers, infants showed the complex combination of (a) orientational/attentional (more time looking) vigilance, (b) interpersonal attentional avoidance (lowered gaze coordination), (c) heightened affective (vocal/engagement) coordination with maternal affect (facial/engagement), and (d) heightened touch coordination with maternal touch. The greater time spent looking at mother, and of en face orientation, but with lowered interpersonal gaze coordination, suggests infant wariness. But infants simultaneously heightened their emotional and touch coordination, an interpersonal vigilance. The self-contingency of the infants' own behavioral rhythms was destabilized in gaze, vocal affect, and facial–visual engagement, likely yielding an experience of lowered self-coherence within the face-to-face interaction.

Evaluating High and Low Poles of Maternal Self-Report Depressive Symptoms. Because self-report scales are vulnerable to denial (Shedler et al., 1993), we hypothesized that report of few or no depressive symptoms may be associated with communication difficulties similar to those associated with report of many symptoms. Half the findings were nonlinear, where altered self- and interactive contingency patterns were similar at both high and low poles of CES-D

(compared to dyads with mothers scoring midrange CES-D); however, several findings were subtle and would require explication with a different method.

Although we are intrigued by these nonlinear findings indicating difficulty at the very low CES-D pole, possibly indexing maternal "denial of distress," we remain cautious. Some mothers reporting very few or no symptoms may indeed be less vulnerable whereas others may be using denial. This is a subject of considerable controversy. For example, Tronick, Beeghly, Weinberg, and Olson (1997) argued that low scores on self-report scales index postpartum "exuberance" whereas Pickens and Field (1993) showed that infant facial expressions of low-scoring mothers were more negative. This debate deserves further consideration.

Limitations

Our examination of maternal 6-week depressive symptoms in relation to 4-month mother–infant contingency patterns is different from the usual cross-sectional design and may make our findings more difficult to compare to the literature. Furthermore, the effects of 6-week maternal depressive symptoms on 4-month mother–infant communication may differ from the effects of 4-month symptoms. We did not investigate whether 4-month CES-D mediates the effects of 6-week CES-D. Nevertheless, it is important that maternal depressive symptoms at this early stage are associated with interaction disturbances $2\frac{1}{2}$ months later. Finally, our analyses addressed the dyadic organization of self- and interactive contingency and did not evaluate how infants may contribute to difficulties, separate from the dyad, with an independent infant measure.

Significance for Mental Health and Intervention

We are currently translating research findings for brief videotape-assisted clinical interventions with mother–infant treatment pairs and with mothers widowed on September 11, 2001, and their young children (Beebe, 2003, 2005; Cohen & Beebe, 2002). If replicable, the current findings can improve the specificity of clinical interventions. Mothers with depressive symptoms can be helped to pay more attention to the infant's necessary cycling of gaze on and off. Perhaps mothers do not track the infant's look–look away pattern because the infant's look away is interpreted as a rejection. These mothers can be sensitized to the importance of infant touch patterns as a source of self-comfort. More affectionate maternal patterns of touch may restore the infant's touch as his or her "own," uncoupled from the mother's touch pattern. Mothers can be helped to lessen their vigilance to the infant's head orientation towards and away, and to the infant's emotional "ups and downs," particularly if it seems that the mother is desperate for the infant's love, overly "thrilled" as the infant becomes more engaged and positive and overly disappointed as the infant becomes more negative. Mothers can be helped to "hold" the infant with more midrange fluctuations of her own, through both interpretive as well as educational strategies (see Beebe, 2003). The findings of lowered self-contingency also are useful clinically. Mothers can be helped to appreciate the importance of their own—and their infant's–stability and predictability, which can be facilitated through educational, interpretive, and imaging strategies.

Conclusion

Four-month mother–infant face-to-face communication was substantially altered in dyads where mothers reported depressive symptoms at 6 weeks. Variations in mother and infant self- and

interactive contingency were equally informative, some of which confirm previous findings, but much of which is new, requiring replication. *Interactive* contingency findings were consistent with our hypothesis that depression biases the system towards the poles of contingency, towards both *higher* contingency values (in some modalities) and *lower* (in others), largely co-created by both partners. Thus, interactive contingency can be "excessive" (i.e., vigilant) as well as "insufficient" (i.e., withdrawn), as we previously have shown (Jaffe et al., 2001). But *self*-contingency was consistently lowered in hi-CES-D dyads, a robust finding not consistent with our hypothesis. The analysis of separate modalities revealed striking, complex intermodal discordances which were forms of intrapersonal and dyadic conflict.

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