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A Transactional Model of Infant Still-Face Response and Maternal Behavior During the First Year

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Face-to-face parent-infant interactions provide a critical context for the development of infant social, communicative, and emotional skills. A large literature supports the contention that parents who readily and accurately interpret their infants' signals and respond in an appropriate, positive, and prompt manner facilitate infant development across multiple domains (Ainsworth, Blehar, Waters, & Wall, 2015; Bowlby, 1983; Feldman, Greenbaum, & Yirmiya, 1999; Tamis-LeMonda, Bornstein, & Baumwell, 2001). Specifically, studies have shown that parenting behaviors such as warmth, sensitivity, and responsivity predict a range of positive infant outcomes including attachment security, language development, and school readiness (Ainsworth & Bell, 1972; Bigelow et al., 2010; de Wolff & Ijzendoorn, 1997; Tamis-LeMonda et al., 2001). Moreover, parents' proclivity to 'read', understand and attribute mental-states (e.g. desires, intentions and beliefs; Meins, Fernyhough, Fradley, & Tuckey, 2001) appear to have unique influences on children's later social and cognitive development (Meins et al., 2003). There is also convergent evidence for associations between "hostile" and "intrusive" parenting in the first year of life and negative childhood outcomes including increased risk for later externalizing and internalizing problems (Belsky, Hsieh, & Crnic, 1998; Edwards & Hans, 2015; Levendosky, Leahy, Bogat, Davidson, & Von

Eye, 2006; Engeland, Pianta & O'Brien, 1993; Murray, Fiori-Cowley, Hooper, & Cooper, 1996).

Although much of the early parenting literature is focused on unidirectional influences of parents on infants, there is increasing evidence to support child effects on parents and transactional models of development (Beebe et al., 2010; Bell, 1979; Chow, Haltigan, & Messinger, 2010; Paschall & Mastergeorge, 2016; Sameroff, 2009). Accordingly, infants are not simply passive recipients of parenting behaviors, but influence parent-infant interactions both through the responses they elicit from parents as well as through their own responses to parenting behaviors. For example, a mother's ability to perceive and interpret her infant's communicative signals is influenced by the saliency and sophistication of those signals (Gros-Louis, West, Goldstein, & King, 2006), and her ability to respond in a positive and appropriate manner will be influenced by the effectiveness of those parenting strategies with her particular infant (Armour et al., 2018). These bidirectional influences not only occur *within* parent-infant interactions, but also occur transactionally *across* time. For example, research on maternal depression suggests that a mother's symptoms and her infant/child's negative affectivity mutually impact one another across time (Murray, Stanley, Hooper, King, & Fiori-Cowley, 1996; Wiggins, Mitchell, Stringaris, & Leibenluft, 2014). Over repeated exchanges, infants develop expectations for their partner's behavior and have been shown to use emotional and communicative cues that shape the style/nature of future interactions with their parents (Bigelow & Birch, 1999; McQuaid, Bibok, & Carpendale, 2009).

The face-to-face still-face (FFSF) procedure was developed as an empirical test of the theory that young infants are able to learn the "rules" of social interactions and become active contributors in regulating the dyadic interaction by modifying behavior based on the feedback they receive from partners (Tronick, Als, Adamson, Wise, & Brazelton, 1978). In the FFSF, parents and infants engage in face-to-face interaction followed by a "still-face" episode during which the parent is asked to hold a still, neutral expression while continuing to look at the infant. The parent then reinitiates interaction in a "reunion" period. With this procedure, it is possible to examine infants' responses to a violation of social expectations as well as their capacity to regulate communicative and affective responses in the face of that violation. A large body of literature has now documented the typical infant "still-face response" (SFR), starting around two months of age, which comprises a reduction in gaze to parent, reduction in positive affect, and an increase in negative affect from the initial period of interaction to the still-face epoch (see Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009 for review and meta-analysis). This pattern of behavior supports the notion that young infants have learned expectations for reciprocity in social interactions and demonstrate a predictable response when those expectations are violated. The affective components of the SFR (increased negative affect, decreased positive affect) are thought to be a reflection of the infant's ability to communicate intentionality to his/her mother using affect, while regulation of gaze has been used as a measure both of social bidding (in the case of looks to the mother; e.g. Carter, Mayes, & Pajer, 1990) as well as self-soothing (in the case of gaze away from mother; e.g. Tarabulsky et al., 2003).

Individual Differences in Infant Still-Face Response and Parenting Behavior

Although the typical still-face response has been well-replicated in the literature, there is significant heterogeneity in observed behaviors and a substantial minority of infants do not show the expected pattern (Mesman, Linting, Joosen, Bakermans-Kranenburg, & van Ijzendoorn, 2013). Given the relevance of infant SFR to regulation of social interaction and emotion, it is no surprise that researchers have become interested in understanding correlates of individual differences in SFR. This field of research has focused largely on how the SFR relates to elements of maternal behavior and mother-infant interactions. The most widely studied correlate of infant behavior during the still face episode is maternal positive parenting behaviors during face-to-face interaction. In a meta-analysis of eight studies examining the relation between maternal “positive parenting behavior” and infant affect during the still face episode, Mesman et al. (2009) reported a medium effect size for the relation between maternal positive parenting and infant positive affect ($d = 0.45$, 95% CI = 0.23–0.66, $p < .01$), but no significant association with infant negative affect. This finding has generally been interpreted to indicate that positive, sensitive parenting leads to better emotion regulation capacities in the infant. However, all eight of these studies examined infant affect during the still face independently of infant affect during the interaction period, and as a result did not shed light on *change* in behavior from the interaction to the still-face periods. For this reason, it is difficult to determine whether infants whose mothers display more positive parenting behaviors are simply more positive overall (i.e. both in the interaction and in the still face epochs), or whether they specifically show less of a reduction in positive affect from the interaction to the still face. One study tested the relationship between maternal sensitivity and change in infant affect and gaze from interaction to still-face and reported no association (Mesman et al., 2013). In this study, maternal sensitivity was, however, associated with a greater reduction in positive affect during the still face for infants rated by their mothers as more temperamentally difficult. This effect was not observed in other infants. This finding provides further support for the transactional nature of parent-infant interactions, highlighting the important role of infant characteristics on dyadic emotional exchanges. Another study examined the relationship between maternal sensitivity during the interaction period and infant dysregulation (characterized by unfocused gaze, active scanning, fussing/crying, agitated activity, negative facial expressions, and autonomic indicators of dysregulation) in all three FFSF episodes (interaction, still-face and reunion). Results showed that maternal sensitivity was negatively correlated with dysregulation in *both* the interaction period and the still face period (Gunning, Halligan, & Murray, 2013), thus providing information about the relationship between maternal sensitivity and infant dysregulation broadly rather than infant dysregulation as a *response* to the still face. Thus, the question of whether and how maternal positive parenting relates to infants’ response to the still face perturbation remains uncertain.

The relations between other aspects of parenting behavior and the SFR are even less well understood. With regard to aspects of parenting behavior that have generally been shown to predict negative outcomes (e.g. intrusiveness, hostility; Belsky et al., 1998; Edwards & Hans, 2015; Levendosky et al., 2006; Engeland et al., 1993; Murray et al., 1996), one study found that infants of highly intrusive mothers exhibited more negative affect during the still-

face epoch and that maternal hostility was associated with a shorter latency to look at mother during the still-face (Kogan & Carter, 1996). However, as with the research on maternal sensitivity, this study only examined infant behavior within the still face episode rather than as change from the interaction period.

There is good reason to believe that maternal mental state talk during mother-infant interactions (i.e. the degree to which mothers talk about their infants' thoughts, intentions, and desires) is particularly relevant to infant SFR, as mothers' perception of their infant as an intentional agent in social interactions may facilitate infants' sense of themselves as active contributors to those social interactions (Meins et al., 2003). Furthermore, to the extent that infants' SFR is a reflection of their ability to perceive and respond effectively to changing dynamics in social interactions, we might also expect that a strong SFR is indicative of the degree to which infants are able to make their needs and desires known in everyday interactions with their mothers. One would expect, then, that infants with a stronger SFR would also have mothers who view them as more intentional, thus suggesting a bidirectional relationship between maternal mental state talk and infant SFR. Nevertheless, we are not aware of any research that has examined the relations between maternal mental state talk and infant SFR.

Relatedly, while several studies have described moment-by-moment bidirectional influences between infants and parents during the interaction portion of the FFSF (Beebe et al., 2010, Cohn & Tronick, 1988, Messinger, 2010), there has been no work considering infant SFR predicting parenting behavior (rather than the reverse). Prior research has shown that aspects of infant temperament, such as high levels of negative emotionality, difficulty, or irritability, predict lower positive parenting behaviors (e.g. responsiveness, sensitivity; Campbell, 1979; Linn & Degen Horowitz, 1983; Malatesta, Grigoryev, Lamb, Albin, & Culver, 1986) and more negative parenting behaviors (e.g. harsh control; Braungart-Rieker, Garwood, & Stifter, 1997). While temperament reflects infants' general tendencies toward arousal and regulation, the FFSF captures the ways infant regulate their affect and behavior in the context of changing social dynamics and thus may be a particularly meaningful predictor of parenting behavior. Infants who are sensitive to changing social dynamics and effective at communicating needs and regulating emotion may provide mothers with more and richer opportunities to engage in sensitive, responsive parenting than infants who show less responsiveness to change or ability to effectively communicate. Thus, a bidirectional view of infant development suggests that infants who show a more pronounced still-face response may, in turn, elicit more positive parenting behaviors and fewer negative parenting behaviors in their mothers. Importantly, other individual differences, such as infant age, sex, and temperament have been shown to relate both to parenting behaviors as well as infant SFR (although results are mixed with regards to impact on SFR; see Mesman et al., 2009 for a review), and thus need to be considered when examining this bidirectional association.

Overall, research examining individual differences in infant SFR has been limited by a lack of diversity in sample demographics. With only a few notable exceptions, research on the FFSF has focused on white, middle-class, well-educated samples. This is particularly surprising given that infants from low-income, urban, and minority families face greater challenges and tend to be at higher risk for poor developmental outcomes (Bradley &

Corwyn, 2002; Noble, McCandliss, & Farah, 2007; Sirin, 2005). Importantly, research that *has* examined more diverse, higher adversity samples suggests that infants in these samples do show a typical SFR (Gunning et al., 2013; Segal et al., 1995; Wagner et al., 2016), but the nature of the association between parenting behaviors and infant SFR in these samples remains an open question.

The Present Study

Despite significant research interest in the still-face phenomenon, findings have been mixed and several important gaps remain. First, most prior research on individual differences in SFR has examined infant behaviors during the still face paradigm in isolation, rather than as *change* from behavior during the interaction period. Second, research has focused almost exclusively on generic “positive” parenting behaviors such as sensitivity, responsivity, and warmth when examining the relationship between parenting and SFR, and little attention has been paid to other aspects of parenting, such as aspects of parenting associated with negative child outcomes (“negative” parenting behaviors; e.g. intrusiveness, hostility; Belsky et al., 1998; Edwards & Hans, 2015; Levendosky et al., 2006; Engeland et al., 1993; Murray et al., 1996) or mental state talk. Third, despite the centrality of bidirectional influences to the original conceptualization of the FFSF paradigm, research has yet to examine infant effects on parenting behavior. Finally, the majority of this research has been conducted with homogenous samples of mostly white, educated, married women and their infants and more sociodemographically diverse samples have been neglected.

In the present longitudinal study, we examine the bidirectional relationships between infant SFR (defined as change in behavior from interaction to still face epochs) and three parenting dimensions—positive parenting, negative parenting, and maternal mental state talk—in an urban sample of low-income women. Taking a transactional view of mother-infant influence, we tested the following hypotheses:

1. Parenting behavior at 4 months would predict magnitude of infant SFR at 6 months such that more positive parenting, fewer negative parenting behaviors, and more mental state talk would be associated with a more pronounced infant SFR (i.e. greater change in affect and social gaze from interaction to SF) two months later, independent of SFR at 4 months.
2. More pronounced SFR (i.e. greater change in affect and social gaze from interaction to SF) at 4 months would predict more positive parenting, more mental state talk, and fewer negative parenting behaviors at 6 months, independent of parenting behaviors at 4 months.

Methods

Participants

The sample comprised first-time mothers (Mean = 20.32; SD = 1.30; Range: 18 – 24) selected from the Pittsburgh Girls Study, a population-based prospective study that has followed a sample of 2,450 urban-living, racially diverse girls from childhood through early adulthood (see Keenan et al., 2010 for details). Participants who were at least 18 years old

and had delivered a healthy, first-born infant to whom they provided at least 2 hours of childcare daily met initial eligibility criteria and consented to participate in a longitudinal substudy assessing postpartum psychopathology that included a neuroimaging component ($n = 189$; see Hipwell et al., 2016; Moses-Kolko et al., 2016). The study was conducted according to guidelines laid down in the Declaration of Helsinki. All subjects provided written informed consent as approved by the University of Pittsburgh Institutional Review Board before any assessment or data collection.

Mothers were largely Black/African American (84.3%) and receiving public assistance (90.8%). About a quarter of the mothers (23.78%) had some post-secondary education, while the rest had a High School Diploma/GED (47.57%) or below (28.65%). Infants were about half female (55.3%). At the 4-month time point, infants were 4.12 months old on average ($SD = 1.08$; Range: 2.33–6.97), and at the 6-month time point infants were 6.8 months old on average ($SD = 0.93$; Range: 5.23–9.70).

Procedure and Measures

At around 4 months postpartum, participants were invited to bring their infants to the research suite to complete filmed observations of mother-infant interactions and an interview. Interactions occurred during times when the infant was alert and not distressed and contained both structured and unstructured segments. Measures were repeated at a follow-up visit at 6 months. Of 189 subjects with a 4-month visit, 19 (10%) participants were excluded prior to the 6-month visit due to MRI contraindications (i.e. unable to participate in the neuroimaging component of the study due to factors that would endanger the participant or interfere with data collection, for example presence of metal in the body) or substance abuse, and 22 (12%) were lost to follow up, leaving a total of 148 infants with a 6-month visit.

Observed behavior.—Mother-infant dyads participated in a two-minute warm-up and three-minute toy play segment during which mothers were first instructed to “talk to your infant in any way you want to” without the use of toys, followed by an episode of toy play when the mother was asked to “help your child to get interested” in a specific toy. Mothers were then prompted to adopt a neutral, still face for 3 minutes. The still-face episode was terminated early if infants engaged in continuous hard crying for 20 seconds. Finally, mothers resumed interaction with infants for a 3-minute reunion period.

Out of 189 participants assessed at 4 months, five (2.7%) were missing observational data due to: technical difficulties ($n = 2$); inability to attend the session in the lab ($n = 1$); or infant distress ($n = 2$). Out of 148 participants with visits at 6 months, four (2.8%) were missing observational data due to: technical difficulties ($n = 1$); inability to attend the session in the lab ($n = 2$); or infant distress ($n = 1$). Thus, data were available for analysis for a total of 184 participants at 4 months and 144 participants at 6 months.

Observational Ratings.—Mother and infant behavior during the warm-up, toy-play, and still-face episodes were rated by graduate-level trained observers using global rating scales based on the frequency and intensity of observed behaviors. Descriptions and details of all rating scales for maternal and infant behavior are presented in Table 1. The use of global

ratings scales made independent observational coding of mother and infant behavior feasible for the large number of participant videos ($n=328$) used in the current study. All raters were trained by an experienced, doctoral-level researcher (AH) through a systematic process. Raters first watched and discussed videos together with the trainer to familiarize themselves with the rating scales. They then coded a series of practice videos along with the trainer and discussed discrepancies. Once coders were achieving consistent agreement with the trainer, they began coding independently.

Maternal warmth, involvement, sensitivity, hostility/irritability and intrusive behaviors were rated during the warm-up and toy play episodes using 4-point rating scale (Hipwell, Guo, Phillips, Swain, & Moses-Kolko, 2015; Hipwell et al., 2016; Morgan et al., 2017). In addition, maternal mental state talk was rated using a 4-point rating scale based on the relative frequency of comments made that attributed skills, intentionality and abilities to the infant, reflecting a belief that the baby could play an active role in or have an impact on, the environment (Hipwell, Guo, Phillips, Swain, & Moses-Kolko, 2015; Hipwell et al., 2016). This system of rating scales has been used in prior work demonstrating their utility and validity (Hipwell, Guo, Phillips, Swain, & Moses-Kolko, 2015; Hipwell et al., 2016; Morgan et al., 2017). In addition, infant positive affect, negative affect, and gaze to mother were coded on 5-point scales during warm-up, toy play, and still-face episodes. The same rater coded both mother and infant behavior within each of the warm-up and toy play segments of the task. However, the warm-up and toy play segments were coded by separate raters. Raters were unaware of all other information about the dyad.

Reliability.—Inter-rater reliability was determined by intra-class coefficients (ICCs) on a random sample of 28 mother–infant pairs for the interaction (infant positive affect ICC=0.91, infant negative affect=0.94, infant gaze to mother=0.95, maternal warmth ICC. = 0.84, maternal involvement ICC. = 0.77, maternal sensitivity ICC = 0.82, maternal hostility/irritability ICC=0.88, maternal intrusiveness ICC=0.91; maternal mental state talk=0.89) and 27 randomly selected pairs for the still-face episode (infant positive affect ICC=0.92; infant negative affect ICC=0.94; infant gaze to mother ICC=1.00).

Interview Measures.—Mothers reported on maternal age, infant age, maternal race, years of education, and past year receipt of public assistance (e.g. WIC, Medicaid), which was used as an index of household poverty. In addition to demographic variables, infant temperament and maternal depressed mood were measured via mother report and included as covariates in analyses as these measures have been previously linked to infant still face behavior (Field et al., 2007; Forbes, Cohn, Allen, & Lewinsohn, 2004; Mesman et al., 2013) and maternal parenting behavior (Armour et al., 2018; Lovejoy, Graczyk, O'Hare, & Neuman, 2000).

Infant Temperament.: Mothers completed the Infant Characteristics Questionnaire (ICQ; Bates, Claire, & Lounsbury, 1979) at a 10 week home visit and at the 6 month visit. The ICQ is a 24-item measure of parents' perceptions of their infants' fussy/difficult temperament rated on 7-point scales (1 = most easy/optimal temperament to 7= most difficult temperament). The ICQ has demonstrated adequate convergent validity with other parent-

report measures of infant temperament as well as the independent impressions of trained observers (Bates et al., 1979).

Maternal Depressed Mood.: Mothers completed the Edinburgh Postnatal Depression Scale (EPDS; Cox, Holden, & Sagovsky, 1987) at the 4- and 6-month visits. The 10 items of the EPDS assess severity of depressed mood, anhedonia, guilt, anxiety and suicidal ideation experienced in the past 7 days on 4-point scales, with higher scores indicating more severe depressed mood. The EPDS demonstrates satisfactory validity, split-half reliability and has been shown to be sensitive to changes in the severity of depression over time (Cox et al., 1987).

Data Analytic Plan

For both mother and infant variables, scores from the warm-up and toy play interactions were averaged to create one score for the interaction period. In order to examine infant still-face response (SFR), infants scores for positive affect, negative affect, and gaze to mother in the interaction period were subtracted from respective scores in the still face period. Thus, positive scores indicate increased behavior in still face compared to interaction and negative scores indicate decreased behavior. Scores for maternal ratings of warmth, involvement, and responsiveness were used in a latent variable model of “positive parenting” (see below). Because a latent variable model with only two indicators is under-identified and therefore not recommended (Little, 2013), ratings of maternal hostility/irritability and intrusiveness were averaged together to create a “negative parenting variable”. Maternal hostility/irritability and maternal intrusiveness were significantly correlated at 4 ($r = .275$; $p < .001$) and 6 ($r = .241$, $p = .004$) months.

Structural equation modeling was conducted using the lavaan program in R. Prior to analysis, we examined skewness and kurtosis for all variables. Variables did not excessively violate assumptions of non-normality (skewness index >3 ; Kurtosis index >10 ; Weston & Gore, 2006), however measures of maternal involvement at 4 months and maternal negative parenting at 4 months had negative and positive skews greater than 1 respectively, and therefore estimation with robust (Huber-White) standard errors was used for analyses of positive and negative parenting behavior.

Given the longitudinal nature of the analyses, we excluded data from three participants who had less than 1 month between their 4- and 6-month visits and one infant with only 4-month data whose age at the 4-month visit (7.07 months) fell outside the range of 4-month visit ages among infants who had both 4-and 6-month visits (Range: 2.33–6.97). Thus, data were included for 185 subjects with either 4- or 6-month data ($N = 180$ at 4 months; $N = 141$ at 6 months). Attrition analyses on the remaining sample of 185 subjects revealed no significant differences between infants with and without 6-month data with regards to infant sex, infant age at 4 months, maternal age at 4 months, race, high school education status, household poverty, or observed mother-infant behavior at 4 months. Thus, in order to make use of all available data, full information maximum likelihood (FIML) estimation was used.

We tested our hypotheses regarding the effect of infant SFR on parenting behavior and the effect of parenting behavior on infant SFR, using a cross-lagged structural equation model

(reciprocal model) for each of the three measures of parenting behavior (Positive Parenting, Negative Parenting, and Mental State Talk) including autoregressive effects, covariances (between variables assessed at the same age), effects of infant still face behaviors at 4 months on parent behavior at 6 months and effect of parent behavior at 4 months on infant still face behaviors at 6 months. Maternal education, mother age, and infant sex were included as time-invariant covariates, while maternal depression severity, infant age, and infant difficult temperament (from the ICQ) were included as time-varying covariates. Figure 1 displays an example of the basic model used in all three analyses.

Establishing factorial invariance for positive parenting latent factor.—As noted above, the “positive parenting” latent factor comprised three indicator variables: maternal warmth, involvement, and responsiveness. Latent variables were identified by setting the latent variance to 1.0, and the scale for the mean structure was set by fixing the latent means to 0. In order to establish measurement invariance across the 4- and 6-month time points, a series of increasingly constrained models were run to sequentially test for configural, weak, and strong invariance.

The configural model had good fit ($I^2 = 6.29$, $p = .28$; CFI = 1; RMSEA = 0.04, 95% CI: 0 – 0.11; SRMR = .03). When factor loadings were constrained to be equal to test for weak invariance, model fit did not differ significantly from the configural model ($I^2 \text{ difference} = 2.89$, $df = 2$, $p > .05$), indicating that factor loadings were equivalent across time points. Next, we constrained factor intercepts to equality to test for strict invariance. The model testing for strict factorial invariance had significantly worse fit than the weak factorial invariance model ($I^2 \text{ difference} = 34.37$, $df = 2$, $p < .001$), indicating some invariance in intercepts across timepoints. We tested for partial invariance by examining modification indices and rerunning the strong factorial invariance model while allowing the intercepts for maternal involvement to be estimated freely. This partial invariance model did not differ significantly from the weak invariance model ($I^2 \text{ difference} = 2.82$, $df = 1$, $p > .05$), indicating adequate partial invariance. The partial invariance model was used in our final cross-lagged panel model for positive parenting.

Results

Table 2 displays descriptive statistics for covariates, parenting variables, and infant SFR variables. As can be seen in the table, for the sample as a whole, mothers were rated relatively highly on positive parenting behaviors (warmth, involvement, and responsiveness), and relatively low on negative parenting behaviors. On average, infants displayed a significant increase in negative affect and decrease in positive affect from interaction to still face at both 4 and 6 months. At 4 months, as a group, infants did not show the typical decrease in gaze to mother from interaction to the still face episode, however this was apparent by 6 months.

Positive Parenting and Infant SFR

Figure 2 displays the cross-lagged panel model of the latent factor for positive parenting and the three infant SFR behaviors (change in positive affect, negative affect, and gaze to mother) from the 4- to 6-month time points. Model fit was good (scaled test statistics:

$I^2 Scaled(102) = 113.18, p = .21$; CFI robust = 0.97; RMSEA robust = 0.02, 95% CI: 0 – 0.05; SRMR = .04). Results revealed a significant cross-lagged effect of change in infant positive affect from interaction to still face on later positive parenting behavior such that a greater reduction in positive affect during still face at 4 months was associated with increased positive parenting behavior at 6 months ($\beta = -0.22, p = .01$). Change in negative affect and gaze to mother were not significant predictors of later Positive Parenting. Conversely, positive parenting at 4 months did not significantly predict any of the three infant SFR behaviors at 6 months.

Negative Parenting and Infant SFR

The cross-lagged panel model for negative parenting is displayed in Figure 3. Model fit was good: (I^2 scaled (34) = 42.51, $p = .15$; CFI robust = 0.94; RMSEA robust = 0.04, 95% CI: 0.00 – 0.07; SRMR = .03). The model revealed that a greater reduction in infant positive affect from interaction to still face at 4 months was associated with less negative parenting behavior at 6 months ($\beta = 0.23, p = .01$). In contrast, negative parenting at 4 months did not significantly predict infant SFR behaviors at 6 months.

Maternal mental State Talk and Infant SFR

Figure 4 displays the cross-lagged panel path model for maternal mental state talk. Model fit was adequate (I^2 (34) = 45.25, $p = .09$), CFI = 0.91, RMSEA = 0.04, 95% CI: 0 – 0.07, SRMR = .04). Results indicated a positive path coefficient from change in infant gaze to mother during still-face to maternal mental state talk at 6 months. Specifically, increased infant-to-mother gaze from interaction to still face at 4 months predicted higher levels of maternal mental state talk at 6 months ($\beta = 0.15, p = .05$), while change in infant positive affect and change in negative affect were not predictive of the extent to which mothers used mental state talk in interaction. Frequency of maternal mental state talk at 4 months was not predictive of any aspect of infant SFR at 6 months.

Discussion

The current study used cross-lagged structural equation models to test transactional effects of observed parenting on infant behavior and infant behavior on parenting in the context of the FFSF paradigm. While previous research has established a cross-sectional relationship between parenting and infant behavior during the still-face, the current research is the first, to our knowledge, to examine these transactional patterns across time, allowing for the identification of specific directional pathways. The present study also extended prior research by examining change in infant behavior from interaction to still-face (rather than focusing on still-face behavior in isolation) and by probing several aspects of parenting behavior. Furthermore, we examined these relationships in a large sample of low-income, minority mothers and their infants; an under-represented population in previous research on the FFSF.

Results provided support for our hypothesis that aspects of infant SFR would predict later parenting behavior. Specifically, findings revealed that a larger reduction in positive affect from interaction to still-face at 4 months was associated with increased positive parenting

behaviors and decreased negative parenting behaviors 2 months later, and that an increase in infant-to-mother gaze from interaction to still face at 4 months was associated with increased maternal mental state talk 2 months later. These findings were independent of parenting at 4 months and significant while controlling for a number of relevant infant and maternal variables, including infant temperament and maternal depression.

Previous research has reported cross-sectional associations between positive parenting variables and infant positive affect during the still face such that greater positive parenting is related to greater positive affect in the child (Mesman et al., 2009). These results have been interpreted to indicate that infants of more sensitive, responsive mothers have better emotion regulation abilities, suggesting a unidirectional effect of maternal behavior on infant behavior. The present study provides new evidence that a greater reduction in positive affect from interaction to still face predicts positive parenting behavior, pointing to infant effects on parenting behavior rather than the reverse association. A major limitation of previous research has been the examination of infant behavior in the still face independent of infant behavior during the interaction period. Rather than providing information about the relationship between parenting and infant *response* to the still face, the results of prior studies describe the relationship between parenting behavior and infant overall behavior during the still face episode. Thus, the positive relation that has previously been reported between maternal positive parenting and positive affect could be explained by a general correlation between positive parenting and infant positive affect, regardless of the type of interaction. Note that the current results do not contradict these previous findings—positive parenting could be related to more *overall* positive affect during the still face (as has been shown in previous research) and also be related to a *reduction* in positive affect from interaction to still face (as shown in the present study). This would be the case if infants of mothers with more positive parenting behaviors both show more positive affect overall and also show a greater reduction in positive affect when faced with the still-face perturbation.

Our findings of infant effects on parenting are consistent with theoretical accounts of development suggesting that individual differences in infant characteristics and behavior evoke different responses from their social environments (e.g. an evocative genotype to environment effect; Scarr & McCartney, 1983). The way in which infants respond when faced with a violation of typical social interaction is theorized to reflect several aspects of infant characteristics and abilities, including attunement to social dynamics, ability to communicate emotions and desires effectively, and emotion regulation skills (Adamson & Prick, 2003; Tronick, Als, Adamson, Wise, & Brazelton, 1979). Change in positive affect from interaction to still face may be a particularly good indicator of infants' ability to perceive and regulate affect in the face of changing social dynamics—a skill that may, in turn, facilitate mothers' opportunities to engage in sensitive, responsive parenting. For example, infants who show large changes in positive affect from periods of non-interaction to periods of interaction (i.e. become highly positive when interacting with their mothers) and vice versa may be particularly rewarding social partners for mothers. In other words, infants who respond positively to interactions and reducing positivity when interactions stop may provide mothers with more enjoyment in interactions, making it easier to tune in and respond to infant signals and thereby increasing positive parenting behaviors. On the other hand, infants who do not show much of a distinction in positive affect from interactive to

non-interactive periods might be less rewarding social partners, potentially leading to maternal frustration or agitation during interactions and increasing negative parenting behaviors. While the mechanism of these relations cannot be determined from the present study data, future research examining moment-by-moment dynamics between child and parent behavior could add to our understanding of these infant effects.

The specific finding that increased rates of infant gaze to mother from interaction to still face predicts mothers' mental state talk suggests that parents may view this aspect of infant behavior as a sign of intentionality. While it is typical for infants to look away during the still face, gaze can be used by infants as a way of "bidding" for their mother's attention (typically in combination with smiles, vocalizations, or reaches), particularly early on in the period (Carter et al., 1990; McQuaid et al., 2009). Infants who show this increased gaze to mother during the still face period may be better at communicating their intentionality and pulling for their mothers' attention, and the mothers of these infants may therefore be more aware of and able to perceive their infants' mental states. Further analysis of the timing of gaze during the still face and overlap of gaze to mother with other communicative behaviors (such as vocalizations or affect) could enrich our understanding of this finding.

Contrary to hypotheses, infant change in negative affect was not predictive of any future parenting behaviors. This finding is consistent with the meta-analysis conducted by Mesman et al. (2009) which reported a significant relationship between positive parenting and infant positive affect during the still face epoch, but did not find a consistent relationship with negative affect. Most infants display only minimal negative affect during the interaction and then increase in negative affect from interaction to still face. It may be that change in negative affect during this paradigm is not as sensitive a measure of individual differences as other aspects of the SFR (e.g. decrease in positive affect).

Our hypothesis that parenting behaviors at 4 months would influence infant SFR two months later was also not supported. While parenting behaviors undoubtedly influence infant behaviors in general, this may not be captured in this type of manipulation. It may be that the still face is such an anomalous experience for infants, regardless of their mothers' parenting style, that the SFR captures the infants' response to an unexpected event and is less influenced by subtle differences in parenting behaviors. Another possibility is that the influence of parenting behaviors on SFR occurs in a non-linear or heterogeneous fashion that has not been captured here. For example, as suggested in research with older children, experiences of harsh or negative parenting may elicit heightened or blunted stress responses in children (Carpenter, Shattuck, Tyrka, Geraciotti, & Price, 2011; Heim, Newport, Bonsall, Miller, & Nemeroff, 2001). It is thus possible, even in the first postpartum year, that negative parenting may predict *both* a very small or a very large still face response in different individuals. Examining the influence of this potential between-dyad variability with biobehavioral indices will be an important avenue for further investigation. Future research extending this transactional model to later infant outcomes, such as attachment, language and communication development, and emotion regulation skills, would also help to enrich our understanding of how infants and mothers mutually influence one another.

Limitations

Despite some important strengths of the current study (e.g. inclusion of a large, well-characterized sample, longitudinal data), a few limitations should be noted. First, the interaction portion of our still-face procedure differed from the traditional procedure as it combined the traditional face-to-face interaction with an interaction involving a toy. It is possible that this change in procedure dampened the strength of the traditional still-face effect, particularly with regard to the infant's gaze to the mother. For example, the presence of a toy for part of the interaction period may have reduced the amount that infants looked to their mother's face during the interaction, which may have impacted the strength in the change in looking from the interaction to still face episodes. While this would not impact the validity of the results (as all dyads underwent the same procedure), it may limit the generalizability of the current study findings.

Furthermore, parent and infant behavior measured during a semi-structured interaction in a laboratory setting may not fully reflect behavior outside the lab. Our interpretation of the infant and parent variables described in this study would be improved by understanding how they relate to mothers' and infants' everyday naturalistic behaviors. In addition, while the global rating of mother and infant behavior allowed us to reasonably use data from a large sample, this type of measurement limits some of our ability to interpret results. For example, global ratings do not allow for analysis of the timing of affective and gaze behaviors during the still face, which may provide more insight into how these behaviors are being used as communicative tools and for emotion regulation. With regards to our ratings of mental state talk in particular, use of global ratings rather than exact frequency counts or proportions may obscure meaningful variability among participants. In addition, future research incorporating more detailed coding of the types of mental state attributions parents make (e.g. whether attributions are appropriate or non-attuned) could provide richer information on the relation between specific types of mental state language and infant behavior. That being said, the use of a global rating scale made the analysis of mother and infant behavior for over 320 participant videos possible, and we believe this makes an important and unique contribution to the field. Furthermore, the descriptive properties and distribution of this variable (see Table 2) suggest that it has captured a range of variability in the use of mental state talk and our ability to successfully achieve reliability adds to our confidence that we are measuring a valid phenomenon. In addition, prior research has demonstrated the validity of brief structural laboratory observations rated with similar global rating scales (Hipwell et al., 2015; Leventhal, Selner-O'Hagan, Brooks-Gunn, Bingenheimer, & Earls, 2004; Shaw et al., 1998).

Finally, although the novel sample of American, low-income, minority mothers and infants is in many ways a strength of this study, the results reported here may not be generalizable to white, middle-class American samples or to mother-infant dyads in other cultural contexts. In addition, it is important to note that certain aspects of parenting behaviors, such as intrusiveness, may carry different meanings for low income and/or Black/African American families than for high income and/or White/European American families. For example, there is mixed evidence on the strength of the relationship between maternal intrusiveness and negative infant outcomes in Black/African American families, with at least some research

suggesting that this relationship may be weaker or negligible compared to the relationship in White/European American families (e.g. Dotterer, Iruka & Pungello, 2012; Ispa et al., 2004). Although intrusiveness was positively correlated with hostility (4 months: $r = .275$; $p < .001$; 6 months: $r = .241$, $p = .004$) and negatively correlated with responsivity (4 months: $r = .35$, $p < .001$; 6 months: $r = -.38$, $p < .001$) in our sample, suggesting that our grouping of parenting variables was valid, without further information about the relation between these variables and later outcomes, we cannot determine the negative and/or positive effects of these behaviors in this particular sample.

Conclusions and Clinical Implications

The research reported here offers new insight into previously reported associations between maternal and infant behavior during the face-to-face still-face procedure. Using a longitudinal cross-lagged model, we establish infant effects on parenting behavior, suggesting that previous unidirectional interpretations of these relationships may have been premature. The findings underscore the importance of examining bidirectional relationships between infant and parent behaviors, and in particular, they highlight the potential influence of infants on parents. Individual infants provide parents with differential opportunities to engage and respond in both positive and negative ways. Acknowledging these infant-effects is critical to the development and implementation of interventions targeting parent-infant interactions. For example, early interventions may benefit from increased discussion of the ways in which infants' behavior impacts their parents' interactions and parenting style. Recognition of these effects may be validating to parents and help them to overcome challenges in implementing new skills with their individual child.

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Figure 1.
Example cross-lagged panel structural equation model

Figure 2.

Final cross-lagged SEM model of positive parenting and infant still-face response from 4 to 6 months. Only covariates with significant effects are shown in the figure, however all covariates were included in the model.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 3.

Final cross-lagged SEM model of negative parenting and infant still-face response from 4 to 6 months. Only covariates with significant effects are shown in the figure, however all covariates were included in the model.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 4.

Final cross-lagged SEM model of mother's mental state talk and infant still-face response from 4 to 6 months. Only covariates with significant effects are shown in the figure, however all covariates were included in the model.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1.

Descriptions of Observational Rating Systems

Variable	Description	Ratings ¹
<u>Maternal Behavior</u>		
Warmth	Positive affect (smiling, laughing) expressed toward the infant.	1 = none; 2 = a little; 3 = some; 4 = a lot
Involvement	Degree to which the mother attended to and engaged with the infant.	1 = minimally; 2 = somewhat; 3 = moderately; 4 = consistently
Sensitivity	Responding appropriately and promptly to the infant's cues.	1 = minimally; 2 = somewhat; 3 = moderately; 4 = consistently
Hostility/Irritability	Negative expressions, including annoyance, critical comments, angry teasing and sharp or harsh tone of voice.	1 = none; 2 = a little; 3 = some; 4 = a lot
Intrusive Behavior	Poking, pulling, lunging face or hands close to the infant's face, and/or loud or high-pitched vocalizations.	1 = minimally; 2 = somewhat; 3 = moderately; 4 = consistently/highly
Mental State Talk	Relative frequency of comments that attribute skills, intentionality or abilities to the baby, reflecting a belief that baby could play an active role in, or have an impact on, the environment (e.g. "You think that's funny?", "You talking to mama?", "You just want to go home".)	1 = none; 2 = 1–2 comments, rare relative to rest of the mother's speech; 3 = 3–5 comments, comprise less than half of mother's speech; 4 = 5 or more comments, comprise more than half of mother's speech
<u>Infant Behavior</u>		
Positive Affect	Frequency and duration of positive facial expressions or vocalizations.	1 = none; 2 = 1–2 brief displays; 3 = several brief displays; 4 = several prolonged/intense/heightened displays; 5 = frequent prolonged/intense/heightened displays
Negative Affect	Frequency and duration of negative/distressed facial expressions or vocalizations.	1 = none; 2 = 1–2 brief displays; 3 = several brief displays; 4 = several prolonged/heightened displays; 5 = frequent prolonged/heightened displays
Gaze to Mother	Frequency and duration of infant looks to mother's face.	1 = none; 2 = 1–2 fleeting looks; 3 = 3–4 fleeting looks or 1–2 longer looks lasting 10 seconds or more; 4 = 3 or more longer looks; 5 = Frequent/prolonged looks

Notes.

¹ Descriptions provided here are meant to be brief summaries of rating system and do not include the full level of detail used for ratings.

Table 2.

Descriptive Statistics for Main Variables of Interest and Covariates

Variable	4 months N = 180				6 months N = 141					
	Mean	(SD)	Range	$t(df)^2$	p-value	Mean	(SD)	Range	$t(df)^2$	p-value
ICQ fussy/difficult ¹	24.11	6.64	9–42			24.39	6.72	9–48		
EPDS severity	3.43	4.22	0–23			3.29	4.12	0–22		
Maternal Warmth	3.34	(0.68)	1.5–4			3.28	(0.70)	2–4		
Maternal Involvement	3.71	(0.46)	2–4			3.33	(0.60)	1–4		
Maternal Responsiveness	3.51	(0.48)	2–4			3.35	(0.61)	2–4		
Maternal Mental State Talk	2.69	(0.87)	1–4			2.11	(0.74)	1–4		
Maternal Negative Parenting Behaviors	1.40	(0.41)	1–3.25			1.48	(0.42)	1–3		
Infant Change in Neg Affect from Interaction to SF	0.85	(1.02)	–1.5–3	–11.23 (179)	<.001	0.71	(0.90)	–1–3	–9.31 (140)	<.001
Infant Change in Pos Affect from Interaction to SF	–0.67	(0.80)	–2.5–2	11.23 (179)	<.001	–0.76	(1.03)	–3–2	8.78 (140)	<.001
Infant Change in Gaze from Interaction to SF	0.09	(1.02)	–2.5–3.5	–1.14 (178)	0.256	–0.27	(0.73)	–2–2	4.35 (140)	<.001

Notes.

¹ ICQ collected at 10wks and 6 months.² Paired-samples t-test comparing infant affect/gaze in interaction period and still face period.

ICQ = Infant Communication Questionnaire; EPDS = Edinburgh Postnatal Depression Scale; Neg = Negative; Pos = Positive; SF = Still-Face.