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Neonatal Risk, Maternal Sensitive-Responsiveness and Infants' Joint Attention: Moderation by Stressful Contexts

Alisa Egotubov[1] · Naama Atzaba-Poria[1] · Gal Meiri[1,2] · Kyla Marks[1,2] · Noa Gueron-Sela[1,3]

Abstract
Neonatal risk factors have been associated with atypical development in various areas of social communication, including joint attention (JA), but little is known about factors in the early caregiving environment that can modify the negative implications of neonatal risk. The present study examines the links between neonatal risk and infants' JA, while considering the mediating role of maternal sensitive-responsiveness and the moderating roles of stressful contexts. One hundred and eighty-two families with infants (50% female) born in a wide range of gestational ages and birthweights participated in the study. Neonatal risk was assessed shortly after birth using three indicators: birthweight, gestational age, and degree of medical risk. At age 6 months, maternal sensitive-responsiveness to infants' foci of attention was rated and maternal anxiety and household chaos were measured. Infants' JA behaviors were assessed at age 12 months. A moderated-mediation model revealed that maternal anxiety symptoms and household chaos moderated the links between neonatal risk, maternal sensitive-responsiveness, and infants' responding to JA. Specifically, neonatal risk was related to less maternal sensitive-responsiveness only when maternal anxiety symptoms were above average levels, but not when anxiety symptoms were low. Moreover, maternal sensitive-responsiveness was positively related to infants' responding to JA behaviors when household chaos was low but not when it was high. These findings highlight the complex nature of the links between infants' early biological risk and caregiving environments in the development of social communication skills.

Keywords Neonatal risk · preterm birth · joint attention · parenting · anxiety · household chaos

Advances in neonatal intensive care during the past decades have vastly improved the survival rates of infants born at heightened neonatal risk (e.g., premature birth, low birthweight, medical complications; Saigal and Doyle 2008). However, research points to the long-term negative impact of neonatal risk factors on a range of developmental domains, including social communication, and more specifically joint attention (JA) abilities (see Zmyj et al. 2017 for review). JA skills are considered a core developmental milestone that lays the foundation for the development of cognitive, language, and social skills (Mundy et al. 2007), and atypical development of JA may be indicative of neurodevelopmental disorders such as autism spectrum disorder (ASD; Meindl and Cannella-Malone 2011). Thus, there is considerable impetus for achieving a better understanding of the mechanisms by which neonatal risk is associated with JA skills.

The biopsychosocial perspective underscores the complex interplay among biological, social, and behavioral factors during the course of a child's development and elucidates multiple pathways to adaptive and maladaptive functioning (Calkins 2015). In this study, we employ this perspective to examine whether the links between infants' biological neonatal risk and psychosocial functioning (i.e., joint attention skills) are mediated and moderated by social factors such as parenting behaviors, maternal anxiety, and household chaos. We specifically focused on three aspects of biological neonatal risk (i.e., birthweight, gestational age, and degree of medical risk) all of which have been related to atypical social-communication functioning (Garner and Landry 1994; Landry et al. 1990; Landry et al. 1998; Olafsen et al. 2006).

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✉ Noa Gueron-Sela
gueron@post.bgu.ac.il

[1] Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel

[2] Soroka Medical Center, Beer-Sheva, Israel

[3] Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer-Sheva, Israel

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The Development of Joint Attention

Joint attention (JA) refers to shared attentional states between two people focused on an object or event of interest, as well as the nonverbal social communication behaviors that precede these shared attentional states (Carpenter et al. 1998). JA behaviors are often classified as to whether they are child-initiated bids or responses on the part of the child to the bids of others (Mundy et al. 2003). *Responding to joint attention* (RJA) refers to the child's ability to follow the communicative gestures of others (i.e., following the gaze shift/head turn or pointing gestures of another to locate an object or event of interest), whereas *initiating joint attention* (IJA) refers to the child's ability to direct the attention of others to spontaneously share experiences (i.e., making eye contact and gesturing to direct the attention of another to an object or event of interest; Mundy et al. 2007). Behavioral manifestations of RJA emerge during the first months of life when infants share eye-to-eye gazes with their caregivers (Butterworth and Jarrett 1991). By 12 months, most infants begin to exhibit IJA behaviors (using gaze and/or pointing/showing gestures). JA skills begin to consolidate toward the age of 18 months but continue to develop throughout the first 3 years of life (Adamson et al. 2014).

JA is considered a hallmark of social-communication skills and has been related to later receptive and expressive language abilities, as well as to multiple aspects of social cognition, such as the understanding of others' mental states (Brooks and Meltzoff 2015). Deficits in JA are often seen among individuals with ASD, but individual differences in JA contribute to variability in outcomes among both atypically and typically developing infants (Meindl and Cannella-Malone 2011; Mundy et al. 2007). Thus, identifying factors that can support or impede the development of children's JA behaviors is of vast importance.

Neonatal Risk and Joint Attention

Neonatal risk factors (e.g., premature birth, low birthweight, medical complications) have been associated with atypical development in various areas of social communication, including reduced response and initiation of JA (De Groote et al. 2006; De Schuymer et al. 2011; Garner et al. 1991; Landry et al. 1990; Zmyj et al. 2017). These social difficulties have recently been attributed to alterations in both gray and white matter in several social brain structures, including the orbitofrontal cortex, the posterior cingulate cortex (PCC), and the temporal lobe, which may be the result of disruptions to typical brain developmental processes occurring during the third trimester of pregnancy (Fenoglio et al. 2017).

Most of the research on this subject has focused on samples of infants born preterm. For example, preterm infants exhibited a reduced ability to follow social gaze during structured observations with an experimenter compared to infants born at full-term (De Schuymer et al. 2011; Olafsen et al. 2006). Likewise, IJA behaviors were less frequently observed among infants born preterm compared to infants born at full-term during both standardized observations with an experimenter and mother-child play interactions (De Groote et al. 2006; Landry et al. 1997; Olafsen et al. 2006). However, there is some inconsistency in the literature regarding deficits in RJA, with some studies indicating impairments only in IJA but not RJA behaviors in preterm infants (De Groote et al. 2006; Landry et al. 1997). The degree of medical risk also seems to play an important role in the development of JA. Preterm infants with higher neonatal risk (as indicated by lower birthweights, lower gestational ages, and severe medical complications) were more likely to suffer from greater difficulties in initiating and responding to joint attention than infants with lower medical risk (Garner and Landry 1994; Landry et al. 1990; Landry et al. 1998; Olafsen et al. 2006). More specifically, infants who developed severe neurological and respiratory complications such as intraventricular hemorrhage (IVH) grades III and IV and bronchopulmonary dysplasia (BPD) seemed to perform less well on JA tasks compared to infants who were not suffering from these conditions (Garner and Landry 1994; Landry et al. 1990). These medical conditions can negatively affect the central nervous system and subsequent social responsiveness through inadequate oxygenation of the brain (hypoxia) as in BPD or from direct brain injury, as in severe IVH (Landry et al. 1990). Therefore, considering a comprehensive continuous measure of medical risk may be more informative to the understanding of the development of JA than considering isolated dichotomous risk factors such as premature vs. full-term birth.

The Mediating Role of Parenting Behaviors

As a first step toward understanding the mechanisms linking neonatal risk and infants' JA, the current study considered the role of maternal parenting behaviors. We elected to focus on this potential mechanism because of the established links between neonatal risk and less optimal parenting behaviors (De Jong et al. 2017; Forcada-Guex et al. 2011) and those between parenting behaviors and children's JA (Mendive et al. 2013).

Parenting behaviors and infants' joint attention It is theorized that JA abilities develop within the early caregiver-child relationship (Bakeman and Adamson 1984; Carpenter et al. 1998). During joint engagement episodes, caregivers' structure and facilitate their infants' JA abilities well before infants are capable of demonstrating these abilities independently. Following and elaborating the infant's focus of attention reduces his or her attentional demands and thereby facilitates focused attention to objects, communication, and joint attention (Mendive et al. 2013).

Research has focused on specific ways in which caregivers regulate their infants' focus of attention. Sensitive responses to infants' attentional states have been defined as instances in which caregivers' responses are congruent with infant's visual focus of attention, appropriate to the infants' state and developmental stage, and elaborate the infant's attentional focus (Mason et al. 2019; Miller and Gros-Louis 2013). Maternal sensitive-responsiveness to infants' attentional focus has been related to infants' JA in real-time interactions. For example, mothers' use of sensitive attention-directing strategies (i.e., following, reinforcing, and elaborating the infant's focus of attention) was preceded by episodes of coordinated JA in which both the mother and the infant were engaged with the same object or involved in the same activity (Bakeman and Adamson 1984; Mendive et al. 2013). Experimental manipulations of sensitivity in both caregivers and experimenters have also demonstrated that when infants interact with a sensitive social partner, they have longer durations of engagement with that partner and increased production of gestures and gesture-vocal combinations toward their partners compared to interactions with a redirective caregiver or experimenter who attempted to change the infant's attentional focus (Miller et al. 2009; Miller and Gros-Louis 2013). Longitudinal studies further demonstrate the potential long-term implications of maternal sensitive-responsiveness for infants' social-communication skills. For example, mothers' use of language that followed their infant's focus of attention at age 9 months positively predicted infants' gestural and linguistic communication skills at age 15 months (Carpenter et al. 1998). Moreover, parenting behaviors that were sensitive to children's focus of attention predicted greater increases and faster growth of social-communication skills between the ages 6 to 40 months (Landry et al. 1998).

Neonatal risk and parenting behaviors Previous research has identified distinct patterns of mother-child interactions among infants at heightened neonatal risk (Forcada-Guex et al. 2011). For example, mothers of preterm infants tended to interact in an active and overstimulating way, in comparison to mothers of full-term infants (Forcada-Guex et al. 2011). In the context of sensitivity to the infant's attentional state, some studies found that mothers of preterm infants used fewer questions to direct the infant's attention and were more directive in their attention-directing strategies (e.g., using commands to control the infant's behavior) than mothers of full-term infants (Garner and Landry 1994; Landry et al. 1990; Landry 1986). A more recent study found that lower gestational age was associated with more maternal redirecting behaviors (De Jong et al. 2017). However, findings regarding neonatal risk and maternal parenting behaviors have been inconsistent. A meta-analysis concluded that mothers of preterm children were not found to be less sensitive or responsive (defined generally as the mother's ability to infer her infant's signals and respond to them appropriately) toward their children than mothers of full-term children (Biligin and Wolke 2015).

The Moderating Role of Stressful Contexts

The diathesis-stress model suggests that individuals with heightened biological vulnerability are more likely to be affected adversely by environmental stressors (Jaekel et al. 2015; Gueron-Sela et al. 2015). Thus, in the current study we examined whether two stressful environmental factors (i.e., maternal anxiety symptoms and household chaos) exacerbated or attenuated the links among neonatal risk, maternal sensitive responsiveness, and infants' JA behaviors (see conceptual model in Fig. 1).

Maternal anxiety symptoms Maternal anxiety can act as a moderator in several ways. First, elevated levels of anxiety can exacerbate the link between neonatal risk and maternal sensitive-responsiveness, which, in turn, may interfere with the development of JA skills (path a, Fig. 1). Infants born at high neonatal risk tend to exhibit unclear emotional reactions, low responsiveness, and high negative affect while interacting with their caretakers, making them more challenging social partners (Feldman 2007; Forcada-Guex et al. 2006). These challenges can be intensified when mothers experience heightened levels of anxiety. Anxiety may trigger the operation of automatic modes of processing and behavior at the expense of controlled processes, reducing mothers' ability to accurately respond to their infants' signals (Yatziv et al. 2018b). Second, maternal anxiety can moderate the direct link between neonatal risk and infants' JA (path b, Fig. 1). Exposure to maternal anxiety can have a negative effect on infants' JA abilities through multiple factors beyond parenting behaviors, such as genetic factors, dysfunctional neurological mechanisms, and exposure to contextual stressors such as marital discord (Murray et al. 2009). Infants born with high neonatal risk may be more susceptible to the negative effects of these factors owing to their innate neuroregulatory deficits (Hartman and Belsky 2018; Gueron-Sela et al. 2015). Finally, maternal anxiety can moderate the link between maternal parenting behaviors and infants' JA (path c, Fig. 1). Exposure to aspects associated with maternal anxiety such as negative modeling of social behavior (De Rosnay et al. 2006) and negative life events and lifestyles (Murray et al. 2009) can reduce the positive effects of sensitive-responsiveness on infants' developing JA.

Household chaos Household chaos refers to the spatial aspects of the physical environment in family households that may elicit stress such as crowding, noise, and lack of routine and

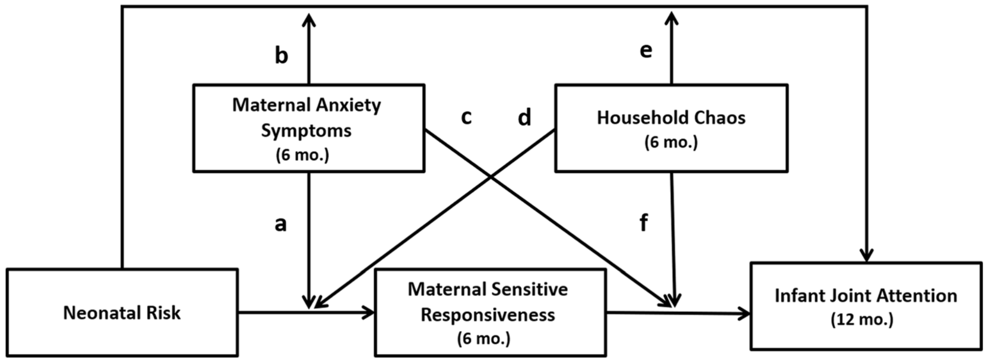

Fig. 1 Hypothesized moderated mediation model specifying paths between neonatal risk and infant JA behaviors at age 12 months via maternal sensitive-responsiveness at age 6 months, moderated by maternal anxiety symptoms and household chaos at age 6 months. Elevated maternal anxiety symptoms can exacerbate the link between neonatal risk and maternal sensitive responsiveness (**a**), as well as the link between neonatal risk and JA behaviors (**b**). Maternal anxiety symptoms can also attenuate the positive link between sensitive responsiveness and infant JA behaviors (**c**). Heightened levels of household chaos can also exacerbate the links between neonatal risk and maternal sensitive responsiveness (**d**), and between neonatal risk and JA behaviors (**e**). Finally, elevated household chaos can attenuate the positive effect that sensitive responsiveness may have on infants' JA (**f**)

schedule (Evans 2006). Chaotic households can exert their influence on infants' JA in multiple ways. First, chaotic household environments can modify the link between neonatal risk and maternal sensitive-responsiveness (path d, Fig. 1). Noisy, unpredictable environments can reduce mothers' abilities to respond sensitively to their infants' bids (Coldwell et al. 2006), particularly when caring for more challenging infants that exhibit unclear emotional reactions and elevated negative affect. Second, household chaos can exacerbate the direct link between neonatal risk and infants' JA (path e, Fig. 1). Infants born with high neonatal risk are often characterized by atypical sensory processing patterns including visual–auditory, movement, and tactile sensitivities, suggesting a low sensory threshold (Crozier et al. 2016). Thus, they may be particularly sensitive to noisy, overstimulating household environments, which may impede the development of their early social-communication skills. Finally, heightened household chaos can moderate the link between maternal sensitive-responsiveness and infants' JA by attenuating the benefits of positive parenting behaviors (path f, Fig. 1). Environmental confusion and disorganization may cause children to develop strategies to filter out high levels of overstimulating stimulation. However, it would also result in children filtering out facilitative stimulation, such as parenting behaviors that support attentional focus (Evans et al. 1991).

The Current Study

The current study was designed to expand the existing knowledge regarding the associations between infant neonatal risk and JA behaviors. We specifically focused on infants with moderate to low levels of neonatal risk. Moderate preterm neonates (29–33 weeks gestational age) with moderate levels of medical risk constitute 2.06% of all births in the United States, compared to 0.69% of extremely premature births (Trembath et al. 2016). Hence, the long-term developmental outcomes in this population have considerable public health implications. However, this group is currently understudied, and detail is particularly lacking on specific domains of social communications skills that may be negatively affected (Cheong et al. 2017). To address this gap in the literature, the current study examines the links between moderate to low levels of medical risk and JA, a developmental milestone that lays the foundation for the development of more complex social-communication skills.

We test moderated mediation models (see Fig. 1) that specify potential pathways between neonatal risk and infant JA behaviors at 12 months of age via maternal sensitive-responsiveness at 6 months of age and moderation by maternal anxiety symptoms and household chaos. We specifically hypothesized that:

1. Maternal sensitive-responsiveness at age 6 months would mediate the association between neonatal risk and infant JA behaviors at age 12 months. Specifically, neonatal risk will have a negative indirect effect on infant IJA and RJA behaviors through decreased maternal sensitive-responsiveness.
2. High levels of maternal anxiety symptoms at 6 months of age will exacerbate the negative links between neonatal risk and sensitive-responsiveness (path a) and between neonatal risk and infant IJA and RJA behaviors (path b). High levels of anxiety will also attenuate the positive link between sensitive-responsiveness and infant IJA and RJA behaviors (path c).
3. Elevated levels of household chaos at 6 months of age will similarly exacerbate the negative links between neonatal risk and sensitive-responsiveness (path d) and between neonatal risk and infant IJA and RJA behaviors (path e)

and attenuate the positive link between sensitive-responsiveness and infant IJA and RJA behaviors (path f).

Methods

Participants

Participants were full-term and preterm infants and their parents who were enrolled in the Preterm Early Development Study (PEDS), a prospective study of preterm infants' early cognitive and social development. Families were recruited to participate in the study shortly after birth and followed up at ages 6 and 12 months. Hebrew-speaking, two-parent families with singleton infants were invited to participate. Exclusion criteria included significant neonatal neurological complications and birth weight under 1000 g. Two-hundred and twenty-six families participated in the study at the first time point shortly after birth (**56**% preterm). One infant with extremely low birthweight (996 g) was mistakenly recruited to the study, and was excluded from the final analysis. One hundred and eighty-two families agreed to participate in the 6-month time point, and the current study focused on this subset of families. The sample included mothers and infants (males = 50.5%) born at a wide range of gestational ages and birth weights. Demographic information is presented in Table 1.

Procedures

After obtaining Soroka Medical Center's Helsinki Review Board approval, families were invited to participate in the study during the infants' postpartum hospitalization period. Those who agreed to take part signed consent forms. In the neonatal period, demographic and medical information were obtained, and assessments of infants' medical risk were conducted based on infants' medical records. Additional data were collected during home visits when the infants were 6 and 12 months old (ages were corrected for prematurity). When infants were 6 months old, mother-infant free-play interactions were videotaped and then rated off-line by a team of trained coders for maternal sensitive-responsiveness. Mothers were instructed to "play with their infants as they usually do" for 7 min, and a box of age appropriate toys was provided. Mothers also completed questionnaires assessing anxiety symptoms and both parents reported on levels of household-chaos. At 12 months of age, infants participated in a structured task with a research assistant to assess JA behaviors. At all three assessments infants completed additional tasks and parents completed several questionnaires regarding issues that are beyond the scope of this report, some of which are reported elsewhere (Gueron-Sela et al. 2015; Yatziv et al. 2018b).

Table 1 Maternal and Infant demographic information

	M	*SD*	*Range*
Mothers age (years)	30.07	5.60	18.33–45.08
Mothers education (percent)			
>12	8.7%		
Partial high-school diploma	8.2%		
Full high-school diploma	25.7%		
Academic degree	57.4%		
Gestational age (weeks)	35.39	3.5	28–42
Birthweight (g)	2437.37	804.23	1016–4316
Days of hospitalization	11.4	12.3	1–75
Apgar score	9.7	0.81	3–10

Measures

Neonatal risk Infant neonatal risk was assessed by three measures: birthweight, gestational age at birth and a standardized medical risk score (Dilworth-Bart et al. 2009). Medical risk was assessed using the Nursery Neurobiological Risk Score (NBRS; Brazy et al. 1991), which includes seven items: infection, blood pH, seizures, intraventricular hemorrhage, assisted ventilation, periventricular variation, and hypoglycemia. Each item was assessed on a 4-point scale (0 = no evidence to 4 = most severe condition) by a trained research assistant, based on the infants' medical records. The total NBRS was the sum of the scores for each item.

A senior neonatologist at the NICU (KM, author on this paper) trained NGS to complete the NBRS based on the infants' medical records. The training process included completing two examples together with the neonatologist, and then completing 5 individual assessments that were checked by the neonatologist until reaching 100% agreement. Then, NGS trained three research assistants in a similar manner (between 5 and 8 double coded assessments were needed). Formal tests to assess inter-rater reliability were not conducted, which may limit the validity of this measure. However, the RAs consulted with the neonatologist in cases in which the rating was not clear or the medical information was ambiguous.

A Principle Component Analysis (PCA) was conducted using the three neonatal indicators (birthweight, gestational age, and NBRS score). These three factors explained 73.5% of the variance, with loadings ranging from 0.94 to 0.69. Thus, a weighted neonatal risk factor score was calculated based on the results of the PCA.

Household chaos Mothers and fathers completed the short version of the Confusion, Hubbub, and Order Scale (CHAOS; Matheny et al. 1995; Dumas et al. 2005), a widely used scale to measure household chaos that has been found to correlate with observed environmental conditions (Matheny et al. 1995). Parents were asked to indicate the degree to which they agreed with six statements describing different aspects of chaos in their home (e.g., "You can't hear yourself think in our home") on a scale from 1 to 5. Higher scores indicate higher levels of household chaos. One item ("There is usually a television turned on somewhere in our home") was omitted owing to low variability. The CHAOS scale demonstrated relatively low internal consistency ($\alpha = 0.61$ and 0.60 in the current study for mothers and fathers, respectively). These values are consistent with previous reports (Chen et al. 2014, $\alpha = 0.65$; Coldwell et al. 2006, $\alpha = 0.57$), and are expected in scales with a small number of items (Cortina 1993).

In order to obtain a representative picture of the chaos levels in the house, and to increase reliability and validity of this measure, and consistent with previous research using the current sample (Yatziv et al. 2018a), we created a chaos composite score by averaging maternal and paternal total chaos scores ($r = 0.26$, $p < 0.01$).

Maternal anxiety symptoms The State Trait Anxiety Inventory (Spielberger et al. 1970), a 40-item self-report instrument developed to assess levels of anxiety, was used to assess maternal anxiety symptoms. The current study used the state anxiety scale that includes 20 items (e.g., "I have disturbing thoughts"). We specifically focused on state anxiety in order to capture emotional responses associated with parenting high-risk infants that are potentially modifiable and independent of demographic and psychosocial risk factors (Rogers et al. 2013). Higher scores indicate proneness to higher degrees of anxiety ($\alpha = 0.90$).

Maternal sensitive-responsiveness Maternal sensitive-responsiveness coding was based on previous coding schemes that focused on attention-directing strategies (Landry et al. 1997; Mendive et al. 2013), which were modified to consider the extent to which they were sensitive to the infant's focus of attention (Mason et al. 2019). Maternal behaviors during free-play at age 6 months were rated off-line by five trained research assistants. Each 7-min mother-infant interaction was divided into 5-s intervals. For each interval, maternal behaviors were classified into 5 mutually exclusive nominal categories: sensitive-responsiveness, non- sensitive-responsiveness, independent action, on-looking and off-task. The current study focused on the sensitive-responsiveness scale, that involves the use of strategies that identify the optimal level of attentional arousal for the infant and help him or her regulate arousal and affect in order to facilitate and sustain attentional engagement. For example, if the infant exhibits interest in the activity, the mother maintains and expands the infant's focus of attention by facilitating the manipulation of an object, moving the infant, or providing verbal input that structures and expands the interaction. If the infant evidences distress, the mother redirects attention to an object or activity that soothes the infant and allows him or her to resume his or her attentional focus. Maternal sensitive-responsiveness scores were created by calculating the total proportion of sensitive-responsiveness intervals from the 7-min play interaction.

Mother-child interactions were coded by five trained research assistants who were unaware of the study hypotheses and objectives. To assess reliability, 15% of the videos were randomly selected and coded by all five coders. The interrater reliability coefficient for the sensitive-responsiveness scale was ICC = 0.84. Regular reliability checks were conducted during the coding process for an additional 10% of the interactions to ensure that ICC values remained above 0.80. Thus, overall 25% of the videos were double coded for reliability purposes. Disagreements in coding were discussed and resolved by reaching a consensus among the five coders.

To test the construct validity of our coding system for sensitive-responsiveness, we examined the bivariate correlations between scores on the sensitive-responsive scale and ratings of maternal sensitivity that were coded using the Emotional Availability Scales (EA; Biringen 2008), which emphasizes affective aspects such as authenticity of affect and emotional responsiveness to the child. There was a moderate positive correlation between scores on these two scales ($r = 0.31$, $p < 0.001$), suggesting that they tap into some similar aspects of maternal behavior, but represent two distinguishable coding approaches that highlight different aspects of sensitive-responsiveness.

Joint attention Infants' joint attention behaviors were assessed at age 12 months using the Early Social Communication Scale (ESCS; Mundy et al. 2003), a 15–20-min structured observation designed to encourage the infant to use communicative behaviors while interacting with an experimenter. During this task, the experimenter and the infant were seated facing each other at a table, with the infant seated on his or her mother's lap. The experimenter exposed the infant to preplanned structured playful situations that included three active wind-up toys (three trials for each toy), three hand-operated toys (three trials for each toy), and opportunities to interact with the experimenter with a hat, a comb, and glasses and to play a turn-taking game (with a car or a ball). The structured play also included an opportunity to look at a picture book with the experimenter and a set of gaze-following trials (explained in detail below).

The current study focused on two scales from the ESCS: responding to joint attention (RJA) and initiating joint attention (IJA). IJA included the infant making eye contact with the experimenter while manipulating a toy, alternating eye contact between an active toy and the experimenter, showing a toy by raising it toward the experimenter while making eye contact, or using pointing gestures toward a toy. The IJA score was calculated by counting the number of infants' IJA gestures throughout the interaction. RJA was measured using two tasks: a gaze-following task and a book presentation task. In the gaze-following task, the experimenter drew the infant's attention by calling his or her name and pointing to four distinct directions in the room. Then, while looking in the direction of the point, she gently said the infant's name. In the book presentation task, a picture book was opened on the table within the infant's reach. The experimenter then began pointing at different pictures in the book while gently calling the infant's name. For each pointing trial, the infant's reaction (1 = traced, 0 = did not trace) was coded. Scores for each task were calculated by the proportion of traced trials from all of the trials. The total RJA score was the sum of the two tasks scores and ranged between 0 and 2.

Observations were coded by three trained research assistants. Coders were unaware of the study hypotheses and objectives. Interrater reliability coefficients were examined in 20% of the videotapes, which were randomly selected, and were coded by all three coders. The interrater reliability coefficient was ICC = 0.83 for the RJA scale, and ICC = 0.96 for the IJA scale. Regular reliability checks were conducted during the coding process for an additional 10% of the interactions to ensure that ICC values remained high. Thus, overall 30% of the videos were double coded for reliability purposes. Disagreements in coding were discussed and resolved by reaching a consensus among the three coders.

Covariates Both maternal parenting behaviors and infants' JA behaviors have been associated with maternal education levels (Mundy et al. 2007; Neitzel and Stright 2004). Thus, to control for maternal education, mothers' education levels were rated on a scale ranging from 1 to 6: 1 for up to 8 years of education, 2 for 8–10 years of education, 3 for 10–12 years of education, 4 for partial fulfillment of high-school graduation requirements (partial high-school diploma), 5 for complete fulfillment of high-school graduation requirements (full high-school diploma), and 6 for an academic degree. Furthermore, both maternal parenting behaviors and infants' JA behaviors have been previously associated with infant temperament (Aktar et al. 2016; Leerkes and Zhou 2018). Thus, to control for infant temperament, the "fussy/difficult" scale from the Infant Characteristics Questionnaire (ICQ; Bates Freeland, & Lounsbury 1979) was used to assess infant temperament at the age of 6 months (e.g., "How easy or difficult is it for you to calm or soothe your baby when he/she is upset?). Mothers rated each item on a 7-point Likert scale ($\alpha = 0.81$). Low scores reflect a difficult/reactive temperament style. Finally, infant sex has also been associated with JA behaviors, and specifically with the development of IJA (Mundy et al. 2007). Thus, child sex was also controlled for (0 = male).

Missing Data

One hundred and eighty-two families from the original 226 families who participated at the first time point agreed to participated at the 6-month time point. No significant differences were found between the families who did not participate at the 6-months assessment and families that did participate in degree of infant neonatal risk $t(210) = 1.93$, $p = 0.06$ and infant sex $t(224) = 1.42$ $p = 0.15$. However, mothers who did not participate in the 6-months assessment ($M = 4.84$, $SD = 1.18$) had significantly lower education $t(224) = 3.54$ $p = 0.00$ than mothers who participated in the 6-months assessment ($M = 5.31$ $SD = 0.95$). At the 12-month time point,173 families agreed to participate. No significant differences were found between the families who did not participate in the 12-month assessment and families that participated in infant sex $t(180) = -0.70$, $p = 0.48$, maternal education $t(181) = -0.96$, $p = 0.33$, infant neonatal risk $t(174) = -1.32$, $p = 0.19$, household chaos $t(170) = -1.96$, $p = 0.11$, maternal anxiety symptoms $t(180) = -0.44$, $p = 0.34$, and maternal sensitive-responsiveness $t(180)$, $p = 0.76$. Of the 173 families who participated at the 12-month assessment, 3% ($n = 5$) were missing data on infant neonatal risk, 1% ($n = 2$) were missing data on infant temperament at age 6 months, 5% ($n = 9$) were missing data on household chaos at age 6 months, and 1 infant was missing data on RJA at age 12 months. Listwise deletion was applied to handle missing data, and the final analysis was conducted on a total of 156 participants (67% preterm).

Data Analysis

The moderated-mediation analyses were conducted in SPSS, using the PROCESS macro version 3.0 (Hayes 2017). A bootstrapping procedure with 5000 bootstrap resamples was used to estimate 95% confidence intervals. Mediation and conditional mediation effects were supported if the range of the confidence intervals did not include zero. All variables were standardized to ease interpretation. We began by estimating baseline mediation models (i.e., neonatal risk-maternal sensitive-responsiveness – infant RJA/IJA; PROCESS Model 4). In the next step, the hypothesized moderators (i.e., maternal anxiety symptoms and household chaos) were added to the models (PROCESS Model 76). Nonsignificant interactions were pruned from the final models and significant interactions were examined by evaluating simple slopes, as described in Cohen et al. (2003). Moderating variables were plotted at mean-level and at 1 SD above and below the mean. In addition, the Johnson-Neyman technique was used to derive regions of significance for the conditional effects (Aiken and West 1991; Johnson and Neyman 1936). Maternal education level, infant sex, and infant temperament were included in all models as covariates.

Results

Preliminary Analyses

Descriptive statistics and bivariate correlations among primary study variables are reported in Table 2. Maternal anxiety symptoms were positively associated with household chaos. Maternal sensitive-responsiveness was associated with maternal education. Household chaos and maternal anxiety symptoms were both negatively associated with infant temperament, and the negative link between neonatal risk and maternal sensitive-responsiveness approached significance ($p = 0.05$).

Baseline Mediation Model

Prior to exploring potential moderators, a baseline mediations model (PROCESS Model 4) were estimated for RJA and for IJA separately. Coefficients for the full model are presented in Online Resource 1. Maternal sensitive-responsiveness did not mediate the association between neonatal risk and infant JA. Specifically, the path from neonatal risk to maternal sensitive-responsiveness and the subsequent paths to RJA and IJA behaviors were nonsignificant.

Moderation by Maternal Anxiety Symptoms and Household Chaos

In the next step, we added maternal anxiety and household chaos to test moderated-mediation relationships among neonatal risk, maternal sensitive-responsiveness at 6 months of age, and RJA/IJA at 12 months of age (PROCESS Model 76). Coefficients for the full models are presented in Online Resource 2.

RJA Model In the model that predicted RJA, significant interactions were found between neonatal risk and anxiety in predicting maternal sensitive-responsiveness ($\beta = -0.31$, $p = 0.002$) and between maternal sensitive-responsiveness and household chaos in predicting RJA behaviors ($\beta = --0.25$, $p = 0.03$). All other interactions were nonsignificant and were discarded in the final model (Table 2, PROCESS Model 21). A post-hoc simple slopes analysis revealed that when mothers reported mean and high levels of anxiety symptoms (+1 SD above the mean), the negative association between neonatal risk and maternal sensitive-responsiveness was significant ($b = -0.17$, $se = 0.07$, $t = -2.2$, $p = 0.02$; $b = -0.43$, $se = 0.12$, $t = -3.61$, $p < 0.001$, respectively). However, when mothers reported low levels of maternal anxiety symptoms (−1 SD below the mean), the association between neonatal risk and maternal sensitive-responsiveness was nonsignificant ($b = 0.09$, $se = 0.11$, $t = 0.86$, $p = 0.38$). The Johnson-Neyman analysis of regions of significance (Fig. 2) indicated that the link between neonatal risk and maternal sensitive-responsiveness was significant for all values of maternal anxiety symptoms above −0.05 SD of the mean (48.25% of the sample), well within the observed range of maternal anxiety scores (−1.6 to 4.62, standardized scores).

The simple slopes analysis further revealed that the positive association between maternal sensitive-responsiveness and RJA was significant only when household chaos was low (−1 SD below the mean; $b = 0.31$, $se = 0.12$, $t = 2.61$, $p = 0.001$), but not at mean and high levels (+1 SD above the mean) ($b = 0.122$, $se = 0.08$, $t = 1.48$, $p = 0.14$; $b = -0.07$, $se = 0.11$, $t = -0.61$, $p = 0.53$, respectively). A Johnson-Neyman analysis (Fig. 3) indicated that the link between maternal sensitive-responsiveness and RJA was significant for all values of household chaos below −0.25 SD from the mean (49.37% of the sample), which was within the observed range of household chaos scores (−1.38 to 2.21, standardized scores).

Table 2 Correlations Among Primary Study Variables

Variable	1	2	3	4	5	6	7	8	9
1. Neonatal risk	–	0.13	0.08	−0.16*	−0.06	0.00	−0.06	−0.07	−0.10
2. Household chaos		–	0.36**	−0.12	−0.09	−0.10	0.06	−0.04	−0.34**
3. Maternal anxiety symptoms			–	−0.06	−0.05	−0.11	−0.02	−0.04	−0.32**
4. Sensitive responsiveness				–	0.14	−0.03	0.20*	0.02	−0.06
5. Responding to joint attention					–	−0.14	0.09	0.03	0.03
6. Initiating joint attention						–	−0.94	0.08	−0.06
7. Maternal education							–	0.09	−0.11
8. Infant sex (male = 0)								–	−0.03
9. Infant temperament									–
M	0.07	−0.04	33.6	0.67	1.42	19.07	5.27	–	23.81
SD	1	0.83	8.26	0.17	0.41	11.53	0.95	–	3.03
Range	−1.7-2.8	−1.4-2.2	20–73	0.06–1	0.25–2	0–75	3–6	–	15.67–29.67

*$p < 0.05$. **$p < 0.01$

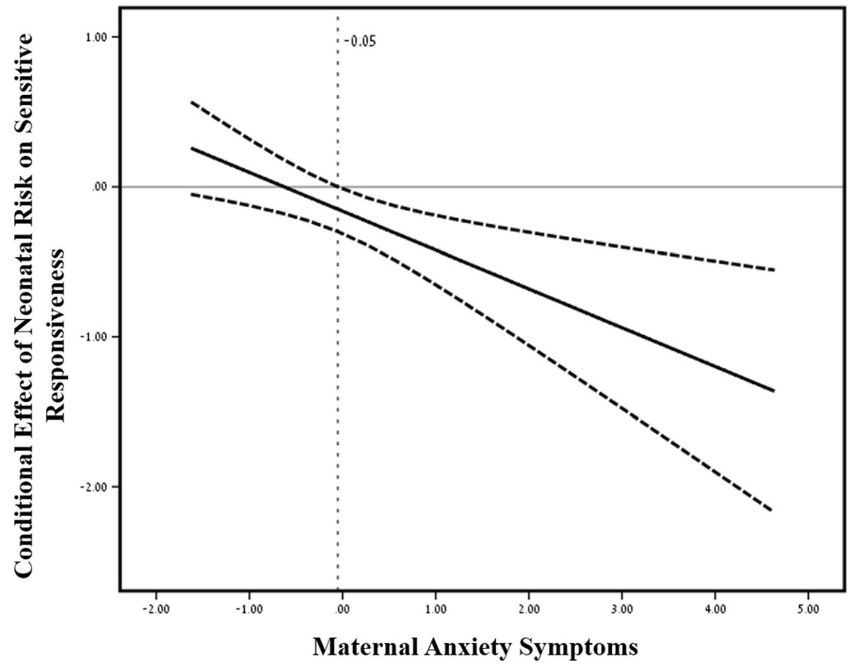

Fig. 2 A visual representation of Johnson-Neyman analysis results, depicting the point-estimate of the slope linking infant neonatal risk and maternal sensitive responsiveness as a function of maternal anxiety symptoms. The dotted lines indicate the upper and lower limits of the 95% confidence interval. Values above − 0.05 (signified by a dotted vertical line) are significantly different from zero

The findings above suggest a dual moderated mediation model (Hayes 2017) in which the indirect effect of neonatal risk on infant JA through maternal sensitive-responsiveness is conditional upon levels of maternal anxiety and household chaos. The *index of moderated mediation* quantifies this effect, and an inference about its value can be used as a test of moderated mediation (Hayes 2017). In this model, the index of moderated mediation was 0.06, with a 95% bootstrap CI that was entirely above zero (0.002–0.048), indicating that the conditional indirect effect was different from zero. Consequently, it can be determined that the association between neonatal risk and RJA is mediated by maternal sensitive-responsiveness only when maternal anxiety symptoms are above average levels and household chaos is below average.

IJA Model In the model that predicted IJA (see Online resource 2), a similar moderation effect emerged for neonatal risk and maternal anxiety symptoms in predicting maternal sensitive-responsiveness. Moreover, a significant interaction was found

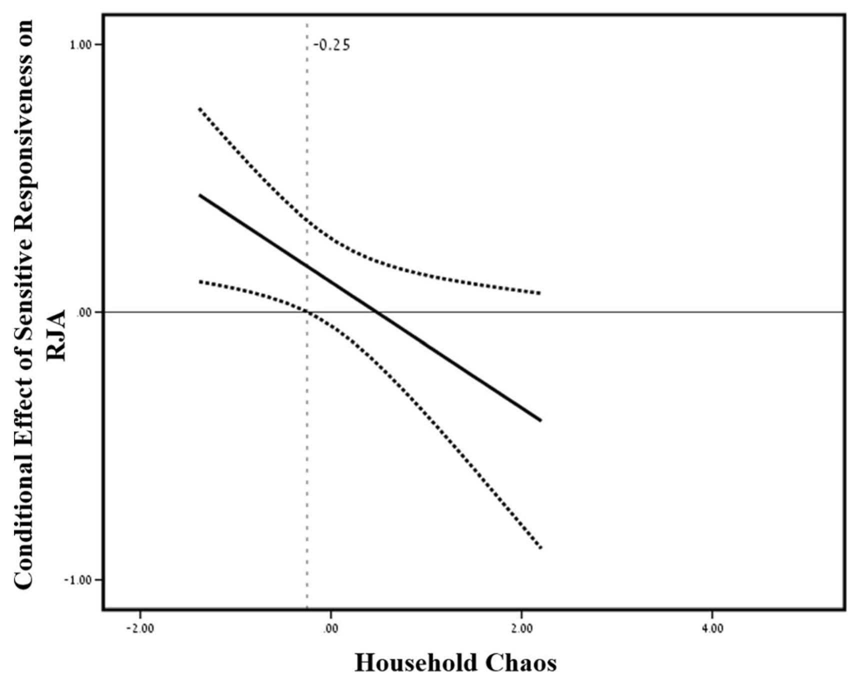

Fig. 3 A visual representation of Johnson-Neyman analysis results, depicting the point-estimate of the slope linking maternal sensitive responsiveness and infant RJA as a function of household chaos. The dotted lines indicate the upper and lower limits of the 95% confidence interval. Values below − 0.25 (signified by a dotted vertical line) are significantly different from zero

between neonatal risk and household chaos in predicting IJA. As maternal sensitive-responsiveness had neither a direct nor an indirect effect on IJA, we removed this variable from the final model and also pruned the nonsignificant interaction terms. In the final model (Table 3, PROCESS Model 1), the interaction between neonatal risk and household chaos was no longer significant ($\beta = 0.17$, $p = 0.07$) (Table 4).

Discussion

In line with biopsychosocial developmental frameworks (Calkins 2015), the primary goal of the current study was to explore the mechanisms that underlie the associations between infant neonatal risk and JA behaviors. We examined the mediating role of maternal sensitive-responsiveness in this association, as well as the moderating roles of stressful environmental contexts (i.e., maternal anxiety symptoms and household chaos) on the hypothesized mediational chain. Overall, our results were consistent with a dual-moderated mediation model (Hayes 2017), in which the indirect effect between neonatal risk and infant RJA through maternal sensitive-responsiveness was conditional upon levels of maternal anxiety and household chaos. Specifically, maternal sensitive-responsiveness mediated the link between neonatal risk and infants' RJA behaviors only when maternal anxiety levels were above average and household chaos was below average (within the values of the current sample). No mediation or moderated-mediation effects were found in predicting infants' IJA behaviors.

Neonatal Risk, Parenting Behaviors, and Joint Attention

Previous research has demonstrated associations between neonatal risk and JA behaviors (De Groote et al. 2006; De Schuymer et al. 2011; Landry et al. 1990; Olafsen et al. 2006) and neonatal risk factors and parenting behaviors (De Jong et al. 2017; Forcada-Guex et al. 2011; Landry 1986), as well as the possible contribution of sensitive maternal behaviors to infants' JA behaviors (Mendive et al. 2013; Olafsen et al. 2006). Thus, we expected that maternal sensitive-responsiveness would mediate associations between neonatal risk and infants JA skills at 12 months. However, this mediation hypothesis was not confirmed. First, in contrast to previous research (Landry et al. 1990; Olafsen et al. 2006; Zmyj et al. 2017), infant neonatal risk did not directly predict infant JA behaviors at 12 months of age. These incongruent findings might be attributed to different sample characteristics in the different studies. Previous studies that found links between

Table 3 Final Model Predicting Responding to Joint Attention via Maternal Sensitive responsiveness, Moderated by Maternal Anxiety Symptoms and Household Chaos

	ß (SE)	[LCI, UCI]
Outcome: Sensitive responsiveness		
Neonatal risk	−0.171*(0.078)	[−0.325,-0.017]
Maternal education	0.189* (0.077)	[0.036,0.342]
Infant sex	−0.031(0.077)	[−0.184,0.122]
Infant temperament	−0.120(0.082)	[−0.281,0.041]
Maternal anxiety	−0.072 (0.083)	[−0.237,0.092]
Neonatal risk X Maternal anxiety	−0.291** (0.091)	[−0.471, −0.110]
F	3.68**	
R^2	0.129	
Outcome: RJA		
Neonatal risk	−0.031 (0.084)	[−0.197,0.134]
Maternal education	0.079 (0.084)	[−0.086,0.245]
Infant sex	−0.008(0.082)	[−0.170,0.155]
Infant temperament	−0.014(0.091)	[−0.195,0.166]
Sensitive responsiveness	0.110 (0.085)	[−0.058, 0.277]
Household chaos	−0.139 (0.109)	[−0.354, 0.076]
Sensitive responsiveness X Household chaos	−0.238* (0.104)	[−0.443, −0.033]
F	1.38	
R^2	0.061	
Conditional indirect effects		
Neonatal risk X Maternal anxiety → Sensitive responsiveness X Household chaos → RJA	0.06 (0.057)	[0.002, 0.048]

*$p < 0.05$. **$p < 0.01$

Table 4 Final Model Predicting Initiating Joint Attention

	ß (SE)	[LCI, UCI]
Outcome: IJA		
Neonatal risk	−0.029(0.085)	[−0.189,0.132]
Maternal education	−0.104(0.081)	[−0.265,0.056]
Infant sex	0.050(0.080)	[−0.109,0.210]
Infant temperament	−0.101(0.084)	[−0.268, 0.066]
Household chaos	−0.203 (0.107)	[−0.415, 0.008]
Neonatal risk X Household chaos	0.173 (0.097)	[−0.019, 0.366]
F	1.37	
R^2	0.052	

*$p < 0.05$. **$p < 0.01$

neonatal risk and JA included infants with lower birth weights and earlier gestational ages (De Schuymer et al. 2011; Landry et al. 1990; Olafsen et al. 2006), hence higher neonatal risk compared to the current study. The degree of medical risk seems to play an important role in the development of JA. For example, some studies have indicated that preterm infants at high neonatal risk are prone to greater difficulties in JA behaviors. Nevertheless, infants at low medical risk demonstrated just slightly fewer JA behaviors than full-term infants (Garner and Landry 1994; Landry et al. 1990; Landry et al. 1997; Olafsen et al. 2006). Second, neonatal risk was not significantly related to maternal sensitive-responsiveness. These findings are in accord with a recent meta-analysis that revealed no evidence of differences in maternal observed parenting behavior between mothers of preterm and full-term infants (Biligin and Wolke 2015), suggesting that there is considerable variability in parenting behaviors in the context of neonatal risk. Finally, contrary to our expectations and several previous studies (Carpenter et al. 1998; Gaffan et al. 2010; Landry et al. 1998; Mendive et al. 2013), maternal sensitive-responsiveness at 6 months did not directly predict infants RJA and IJA behaviors at 12 months. These inconsistent findings can be attributed to methodological differences in the various studies. First, most of the studies that examined the links between maternal behavior and infants JA behavior were cross-sectional (e.g., Mendive et al. 2013), whereas the current study employed a longitudinal design. Thus, maternal sensitive-responsiveness may have stronger immediate than persistent long-term effects on infants' JA behaviors. Second, the two previous studies that did report longitudinal links between maternal behavior and infant JA focused on different aspects of maternal behavior than the current study (Carpenter et al. 1998; Gaffan et al. 2010). For example, Gaffan et al. (2010) found that aspects such as maternal overinvolvement at age 6 months predicted infants' reduced JA behaviors at age 9 months. It is possible that negative aspects of parenting behaviors, as opposed to sensitive-responsiveness as measured in the current study, have more enduring effects on infants' developing JA skills. Finally, Landry et al. (1998) found that maternal use of responsive attention-directing strategies (i.e., maintaining the infant's focus of attention) is related to increases in social initiating behaviors between the ages of 6 and 40 months, suggesting that maternal behaviors are related to rate of growth in JA abilities rather than functioning at a specific time point.

Our null findings regarding the baseline mediation model also speak to the idea that infants' developmental outcomes do not depend solely on immediate interactions with the caregiver but are rather the result of complex interactions among multiple elements in the environment (Bronfenbrenner 1994). For most infants, the most enduring and proximal system is made up of the family and household surroundings (Parke et al. 2006). Accordingly, our next step was to examine whether maternal anxiety symptoms and household chaos moderate the relationship between neonatal risk and maternal sensitive-responsiveness at 6 months of age and of RJA and IJA) at 12 months of age.

Moderation of Stressful Contexts

Maternal anxiety symptoms As hypothesized, maternal anxiety symptoms moderated the link between neonatal risk and maternal sensitive-responsiveness. Only when maternal anxiety symptoms were above average (of the current sample), the negative association between neonatal risk and maternal sensitive-responsiveness was significant. The average score on the STAI measure in the current sample was 33.5, below the suggested clinical cut-off of 39–40 to detect clinically significant symptoms of anxiety (Julian 2011). This implies that even when anxiety symptoms do not reach clinically significant levels, they may impact the manner by which mothers interact with their high-risk infants. These findings also demonstrate the transactional nature of the links between child and parental characteristics. Infants born at heightened neonatal risk tend to be less responsive and communicative in social interactions. For example, during the first year of life preterm infants were found to exhibit ambiguous emotional reactions and increased gaze aversion and were less responsive in play interactions with their caretakers (Feldman 2007; Landry 1986; Landry et al. 1997). Thus, it may be more challenging for caregivers to identify these infants' social cues and respond appropriately. Heightened levels of anxiety may further impede mothers' ability to invest the attentional and emotional resources that are required to respond sensitively to the infant. Anxiety triggers the onset of automatic modes of processing at the expense of controlled processes, leading to reflexive rather than goal-directed behavior (Eysenck et al. 2007). Mothers' self-control and goal-directed behavior might be crucial factors when interacting with challenging infants (Zelkowitz et al. 2009).

Household chaos Consistent with our hypothesis, household chaos moderated the association between maternal sensitive-responsiveness and infants' RJA abilities at age 12 months. Specifically, it was only in the context of a calm and predictable environment that the positive association between maternal sensitive-responsiveness and RJA was significant. However, in noisy, disorganized, crowded home environments infants did not reap the benefits of maternal sensitive-responsiveness. These findings extend previous studies by demonstrating that chaos can also negate the positive contributions that supportive parenting behaviors may have for children's development.

Infants' IJA behaviors Contrary to our hypothesis, no direct or moderated links were found between maternal sensitive-responsiveness and infants' IJA behaviors. These null findings might be explained by the different developmental trajectories of IJA and RJA behaviors. As noted, infants begin to exhibit IJA behaviors by 12 months (Mundy et al. 2007), and these skills continue to consolidate throughout the second year of life. Accordingly, it is possible that individual differences in the development of IJA increase over time during the second year of life. Thus, the potential contributions of parenting behaviors may be evident later on, as was demonstrated in previous studies (Landry et al. 1998).

Limitations and Conclusions

Findings from this study should be considered in light of several limitations. First, infants who participated in this study had overall low to moderate levels of medical risk, and a wide range of gestational ages. Additional research including higher-risk samples (e.g., extremely low-birth-weight infants; birthweight <1000 g) and more homogenous risk groups should be conducted in order to determine whether or not these moderated-mediation processes extend to infants at varying levels of neonatal risk. Moreover, the wide range of gestational ages of the current sample can also explain why we did not find direct links between neonatal risk and the JA measures. Second, we only considered one aspect of parenting behavior that can facilitate infants' JA. Considering additional factors that can impede the development of social attention, such as redirection (i.e., attempts to redirect the infant's focus of attention; Mason et al. 2019; Miller and Gros-Louis 2013), could provide a more comprehensive evaluation of the links among neonatal risk, parenting behaviors, and infants' JA. Finally, the specific sample characteristics in the present study should also be considered when interpreting the findings. Only two-parent families were included in the study, resulting in a relatively moderate to high SES sample which may truncate the range of both maternal anxiety symptoms and household chaos. Testing our model in a diverse sample in terms of SES would enable us to determine the implications of exposure to extreme levels of stress on the development of JA behaviors. With that said, it is noteworthy that even moderate levels of maternal anxiety symptoms and household chaos had a significant role in the link between neonatal risk and JA.

Despite the limitations noted above, important clinical implications can be drawn based on the findings from this study. Neonatal risk seems to have an indirect effect on infants' RJA behaviors via maternal sensitive-responsiveness, but only under certain conditions. First, it predicted lower maternal sensitive-responsiveness only when mothers exhibited above average (within the current sample) levels of anxiety symptoms. This suggests that even symptoms of anxiety that do not reach clinical significance may have a negative impact on mothers' ability to be sensitive to their infants' focus of attention. Given that approximately 50% of mothers in our sample experienced above average levels of anxiety symptoms, it is essential to integrate early screening and monitoring of such symptoms in routine medical follow-ups of infants born at heightened neonatal risk, in order to implement appropriate interventions. Second, only when household chaos levels were below average (within the currents ample), maternal sensitive-responsiveness supported infants' RJA behaviors. When household chaos was above average (approximately 50% of the sample), infants were not able to reap the benefits of sensitive-responsive caregiving. These results speak to the importance of promoting calm, predictable household environments that include regular routines and structure, messages that can be delivered through psychoeducation parenting programs in community agencies, pediatric settings, and early education centers.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national researchcommittee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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