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Infant Patterns of Reactivity to Tactile Stimulation during Parent-Child Interaction

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Abstract

Touch is the primary modality infants use to engage with the world; atypical responses to tactile stimuli may indicate risk for disordered outcomes. The current study examined infants' responses to tactile stimulation within parent-child interaction, adding to prior knowledge based on parent report. Nine-month-old infants ($N = 497$) were observed while parents painted and pressed infants' hands and feet to paper to make designs. Positive and negative affect and gazing away, exploring, and resistance behaviors were coded. Latent Class Analysis of observed behaviors yielded four tactile response patterns partially consistent with current nosology for sensory processing patterns: Low Reactive, Sensory Overreactive, Sensory Seeking, and Mixed Over/Underreactive. To evaluate whether patterns made valid distinctions among infants, latent classes were examined in relation to parent-reported temperament. Infants in the Mixed Over/Underreactive class were rated higher in distress to limitations and activity level than other infants. Sensory processing patterns observed in parent-child interaction are consistent with those identified by parent-report and may be used in future research to elucidate relations with temperament and typical and atypical development.

Keywords

sensory processing; parent-child interaction; temperament

Infants depend on sensory experiences to communicate and bond with caregivers, be successfully soothed, and learn about the world. Indeed, a large body of research has shown that early sensory experiences scaffold the development of higher-order cognitive, motor, and regulatory processes (Cascio, 2010; Feldman, Eidelman, Sirota, & Weller, 2002;

Feldman, Singer, & Zagoory, 2010; Feldman, Weller, Sirota, & Eidelman, 2003). There is also evidence that infants show individual differences in behavioral responses to sensory stimuli (i.e., sensory processing patterns; Baranek, David, Poe, Stone & Watson, 2006; Ben-Sasson et al., 2007; Dunn, 2001; Dunn & Daniels, 2002; Miller, Anzalone, Lane, Cermak, & Osten, 2007; Miller, Reisman, McIntosh, & Simon, 2001). Whereas most infants are able to use early sensory experiences to engage in and learn from their environments, infants with atypical sensory responses (e.g., hypo- or hyper-responsiveness) have difficulty tolerating or responding to sensory input, which may have implications for later development. For instance, atypical sensory responses assessed as early as 8 months have been associated with developmental disabilities, poor motor skills, and difficulties regulating attention, emotion, and behavior (Ben-Sasson et al., 2007; DeGangi, Porges, Sickel, & Greenspan, 1993; Eeles et al., 2013; Mammen et al., 2015).

Much of what is known about infant sensory responding has been obtained through caregiver reports or standardized clinical testing (e.g., DeGangi & Greenspan, 1989; Dunn & Daniels, 2002). Although caregiver reports may assess infants' sensory responses broadly across several contexts, there are disadvantages to relying only on parent report. Clinical observations systematically test infants' responses to a variety of sensory stimuli but do this within the narrow context of a clinical assessment. To extend previous research, the current study observed infants' responses to tactile stimulation during parent-child interaction.

The study focused on responses to tactile stimulation because, as the first sensory system to develop, touch is the primary modality infants use to communicate and engage with the world around them (Cascio, 2010; Ferber, Feldman, & Makhoul, 2008; Jean & Stack, 2009; Montagu, 1986; Moszkowski, Stack, & Chiarella, 2009). Atypical responses to tactile stimuli, in particular, may pose a risk for infant development of age-appropriate social and self-regulatory skills (Field, 2010). Further, infants' responses to touch develop within the parent-child relationship (Dunn, 2004). For instance, an infant who has very high or very low tactile reactivity may interact with caregivers in a way that develops into a stable pattern of avoidance or unresponsiveness during the exchange of tactile stimulation.

Infants' reactions to tactile stimuli that are paired with or, in many cases, inseparable from social and emotional stimuli (e.g., stroking, cuddling, tickling) also may have an influence on the quality of parent-child interactions and evoke distinct responses from caregivers; for instance, atypical sensory responses have been related to higher parenting stress, lower parenting responsivity, and greater restrictions on family activities (Ben-Sasson, Soto, Martinez-Pedraza, & Carter, 2013; DeGangi, 2000; DeGangi, Sickel, Kaplan, & Wiener, 1997; Dunn, 2004; Epstein, Saltzman-Benaiah, O'Hare, Goll, & Tuck, 2008). On the other hand, parents who show more awareness of and responsiveness to their children's patterns of sensory responses have more positive interactions with their children (Jaegermann & Klein, 2010). Therefore, examining infants' patterns of responding to tactile stimuli during parent-infant interactions may be essential for understanding the development of parent-child relationships as well as understanding children's developing self-regulation.

Following conceptual models of sensory processing, discussed below, the current study aimed to examine patterns of infants' responses to tactile stimulation observed during a structured, naturalistic parent-child interaction.

Models of Sensory Processing

Ayres (1979) originally proposed that the way in which the brain processes sensory stimuli results in behavioral responses to the environment and the development of adaptive behaviors. More specifically, the processes of sensitization, or the capacity to register a new sensory stimulus, and habituation, or the capacity to adapt to an ongoing or familiar sensory stimulus, support the individual's ability to organize a behavioral response that is appropriate for the characteristics of a given sensory stimulus. Individual differences in how the brain processes sensory stimuli are believed to result in distinct patterns of responding to sensory input (sensory processing patterns). Atypical sensory processing occurs when individuals show hyper- or hypo-responsiveness or inconsistent responding to sensory stimuli (Miller et al., 2007). Researchers have built on Ayres' work by identifying specific patterns of responding to sensory stimulation from infancy to adulthood, in typically-developing and clinical samples (e.g., Baranek et al., 2006; Ben-Sasson et al., 2007; Dunn, 2001; Miller, Reisman, McIntosh, & Simon, 2001). Most recent conceptualizations propose three distinct patterns of sensory responding: Sensory Overresponsivity, Sensory Underresponsivity, and Sensory Seeking (Miller et al., 2007).

Sensory Overresponsivity, which has been linked to heightened sympathetic nervous system reactivity (Miller et al., 1999), is characterized by responses to sensory stimulation that are quicker, more intense, and prolonged, compared to other children's responses. Infants who are overresponsive to sensory stimuli may show a variety of behavioral responses, including resistance, avoidance, and distress. *Sensory Underresponsivity* is characterized by problems detecting sensory input; underresponsive infants appear to be less sensitive than other children to sensory stimulation, and as a result, show less affect and limited engagement in or exploration of their environments. Research suggests that this sensory processing pattern is less common in typically developing samples and more common in children with developmental disabilities (Tomchek & Dunn, 2007). *Sensory Seeking* is characterized by the pursuit of highly intense or atypically large amounts of sensory stimulation. Although sensory seeking infants also seem to be less sensitive to sensory input, they respond by pursuing sensory stimulation throughout their everyday activities, often maintaining a high activity level to increase the sensory input. As a result, they may be described as highly excitable and may react negatively when sensory input is not achieved (Miller et al., 2007).

These sensory processing patterns comprise the current nosology for diagnosing Sensory Modulation Disorder (Miller et al., 2007), and have been supported by a body of research using caregiver report of children's emotional and behavioral reactions to a variety of sensory stimuli (e.g., Dunn & Daniels, 2002; Schoen, Miller & Green, 2008). Less frequently, sensory processing has also been measured by clinical observations of young children's behavioral responses during systematic exposure to different types and intensities of sensory stimuli (DeGangi & Greenspan, 1989), or responses to multi-sensory toys during play-based assessment (Baranek, 1999).

The Current Study

To date, we are unaware of any measure of infant sensory processing observed during parent-child interaction. This is surprising, based on evidence that interactions between parents and infants occur on a sensory level and that the exchange of sensory stimulation, in particular tactile stimulation, promotes the development of higher-order skills (e.g., cognitive, motor, regulatory) and parent-child relationships (Cascio, 2010; Feldman, Eidelman, Sirota, & Weller, 2002; Feldman, Singer, & Zagoory, 2010; Feldman, Weller, Sirota, & Eidelman, 2003; Hernandez-Reif, Diego, & Field, 2007; Hofer, 1995; Hrdy, 1999). Therefore, the first aim of the current study was to examine infants' patterns of behavioral responding to tactile stimulation during a naturalistic parent-child interaction. We used a structured task that required parents to deliver tactile stimulation to their 9-month-old infants by painting the infants' feet and hands and pressing them on paper to make a picture. Consistent with parent-report measures, which have used child gaze, exploration, and resistance behaviors and affect to assess infant sensory responses (e.g., DeGangi & Greenspan, 1989; Dunn & Daniels, 2002; Goldsmith, 1996), we coded infants' direction of gaze (e.g., toward stimulus, away from stimulus), exploring stimulus (e.g., reaching for or manipulating), resistance (e.g., struggling, pushing or pulling away from stimulus), and positive/negative affect during tactile stimulation. Prior research has shown that individual differences in these behavioral responses to sensory stimulation can be reliably measured by 9 months of age (DeGangi & Greenspan, 1989; Fairhurst, Löken, & Grossman, 2014).

There is also evidence for associations between infant sensory response patterns and parenting behavior; for instance, DeGangi and colleagues (1997) showed that mothers of infants with atypical sensory responses spoke more and showed lower levels of movement and symbolic play, more flat affect, and less attunement with their infants. To account for parenting behaviors that may affect infants' responses to tactile stimuli, parents' specific movements, engagement, and touch behaviors, including affectionate touch and game play, were also measured during the parent-child interaction task and included in analyses.

The second aim of the current study was to examine associations between observed patterns of responding to tactile stimuli and parent reports on a widely-used inventory of infant temperament (Infant Behavior Questionnaire; Rothbart, 1981). Sensory processing overlaps with conceptual models of temperament (e.g., Dunn, 2001, Rothbart, 1981). Indeed, a well-known line of research has focused on whether early physiological and behavioral reactivity to sensory stimuli leads to temperamental behavioral inhibition (e.g., Calkins, Fox & Marshall, 1996; Fox, Henderson, Rubin, Calkins & Schmidt, 2001; Kagan & Snidman, 1991). Although it is unclear whether sensory processing is an underlying component or dimension of temperament or is better conceptualized as a distinct but related construct, a growing body of research has found consistent associations between sensory processing patterns and temperament.

Sensory Overresponsivity has been found to relate to higher temperamental negativity, whereas Sensory Seeking has been found to relate to higher temperamental positivity (Daniels, 2004; DeSantis, Harkins, Tronick, Kaplan, & Beeghly, 2011; Goldsmith, Van Hulle, Arneson, Schreiber, & Gernsbacher, 2006; Klein, Laish-Mishali & Jaegermann, 2008;

O'Boyle & Rothbart, 1996). Most relevant to the current study, overresponsivity to tactile stimulation in particular has been found to correlate highly with temperamental negativity (Case-Smith, Butcher & Reed, 1998; DeGangi & Greenspan, 1988). Activity level, on the other hand, has been found to correlate positively with both Sensory Overresponsivity and Sensory Seeking (Klein et al., 2008; O'Boyle & Rothbart, 1996), though perhaps for different reasons; it is possible that overresponsive children show higher activity level that is related to behavioral reactivity to or resistance of sensory stimuli, whereas children who are sensory seeking show higher activity level due to increased exploration of the environment and pursuit of sensory input.

Relatively fewer correlations have been found between Sensory Underresponsivity and dimensions of temperament, and this may be because this sensory processing pattern is more prevalent in samples with developmental disabilities, such as Autism Spectrum Disorder (ASD) (Tomchek & Dunn, 2007). While evidence suggests Sensory Underresponsivity is related to lower capacity to orient to people and objects in one's environment in typically-developing children (DeSantis et al., 2011), in young children diagnosed with ASD, Sensory Underresponsivity is related to higher temperamental negativity and less capacity to engage in and adapt to one's environment (Brock et al., 2012; Chuang, Tseng, Lu & Shieh, 2012). It is also notable that children with ASD often show more than one pattern of atypical sensory processing, and difficulties across Sensory Overresponsivity, Sensory Underresponsivity, and Sensory Seeking are associated with increased temperamental negativity and withdrawal from the environment in children with ASD (Brock et al., 2012).

The majority of studies examining the relation between sensory processing patterns and temperament have used parent-report measures of both, which could account, in part for overlap between the two. In the only study to date that has compared infants with difficult temperament to other infants on an observational measure of sensory processing, DeGangi and Greenspan (1988) found that infants described as temperamentally difficult (e.g., prone to distress) by their parents showed higher levels of observed Sensory Overresponsivity compared to other infants. Overall, findings from studies of the relation between sensory processing and temperament suggest that infants' observed sensory response patterns would be correlated with parent-reported measures of infant temperamental negativity (distress to limitations and to novel stimuli), temperamental positivity, activity level, and capacity to orient to people and objects within the environment (orienting sensitivity). In addition to the primary aim of identifying patterns of tactile responding during observations of naturalistic parent-infant interaction, the secondary aim of the study was to examine whether the identified patterns would be related to parent-reported dimensions of temperament.

Method

Participants

Participants in the current study were from a prospective, longitudinal study of adoptive families ($N = 561$) in the Pacific Northwest, West/Southwest, Mid-West, and Mid-Atlantic regions of the United States. Each adoption triad consisted of the adopted child, adoptive parents and at least one birth parent, typically the birth mother. Prior publications on this study provide detailed information on recruitment and assessment procedures and detailed sample information (Blinded for Review). This initial study aimed to observe infants' behaviors in response to tactile stimulation during a social interaction and to use latent class analysis to identify distinct groups of tactile response patterns; future research will determine the relative effects of genetic and environmental influences on these tactile response patterns.

The median child age at adoption placement was 2 days (SD = 12 days, range = 0 - 91), and forty-three percent of the sample was female. The current investigation included data collected from the adoptive parents and children when children were 9 months of age (M = 9.30, SD = .59, range = 8.25 - 14.29). In general, adoptive parents were college-educated and middle class (Household Income: median = \$110,000, SD = \$102,7338, range = \$7,000.00 - \$1,500,000.00). Mean ages of adoptive mothers and fathers were 38.2 and 39.2 years, respectively. The sample of adoptive mothers was largely Caucasian (93.0%; African American = 3.0%, American Indian/Alaska Native = 0.2%, Asian American = 0.8%, more than 1 race = 0.8%), as was the sample of adoptive fathers (90.9%; African American = 4.8%, Asian American = 0.6%, Native Hawaiian/Pacific Islander = 0.6%, more than 1 race = 1.2%). Approximately 2.2 percent of adoptive mothers and 1.8 percent of adoptive fathers were Hispanic. On average, adoptive parents had been married for 11.21 years (SD = 5.13, range = .76 - 26.26). The majority of birth parents had completed high school or trade school and most reported household incomes below \$25,000. The mean age of birth mothers was 24.87 (SD = 6.06, range = 14.25 - 44.13), and although the sample of birth parents was more racially diverse than adoptive parents, the majority (71.3%) of birth mothers were Caucasian (African American = 12.2%, American Indian/Alaska Native = 2.8%, Asian American = 1.6%, more than 1 race = 4.9%, unknown/did not report = 0.4%), and approximately 6.7 percent of birth mothers were Hispanic.

Only families (adoptive parents and adopted children) with complete data at the time of the adoptive family assessment (infant age 9 months) were included in the current study (N = 497). The Flower Print Task required the participation of both parents to complete the activity, and data were missing due to: only one parent available to participate because of scheduling constraints (n = 17) or single-parent family (n = 10); technical problems with video/sound equipment (n = 14); and data unavailable at 9 month time point because the family had not yet joined the study or did not participate in the 9 month adoptive family assessment (n = 23). Participating families did not differ significantly from nonparticipating families on indicators of: parental education, parent age, or household income; however, adoptive mothers included in the current study rated their infants as showing significantly lower distress to novelty (M = 2.42) than those excluded (M = 2.58; $F(1, 523) = 3.92$, $p < .05$).

Procedure

The current investigation included data provided by the adoptive parents and observations of adoptive parents and their adopted infants at infant age 9 months. During a 2.5-hour assessment in the home, interviewers asked adoptive parents to complete computer-assisted and paper-pencil interview questions, which each parent completed independently. Adoptive parents also completed several interaction tasks independently with the adopted child and one interaction that included both parents and the infant, The Flower Print Task, which was the focus of the current study. All participants received monetary compensation for volunteering their time to participate in the study. Prior publications on this study provide detailed information on procedures and assessments (Blinded for review).

Infant Responses to Tactile Stimuli during Parent-Child Interaction

The Flower Print Task was originally designed for the study by the third author to assess co-parenting. The task required adoptive parents to paint their 9-month-old infants' hands and feet and then to press them to a piece of paper to create a flower design. The adoptive parents used step-by-step instructions, paper, paintbrushes, several bottles of paint, a bib, and wet wipes and worked together to complete the task. Typically, one parent held and moved the infant while the other parent painted and pressed each of the infant's hands and feet to the paper. Although initially designed to assess the manner in which parents worked together, this task was ideal for assessing infants' responses to tactile stimulation within a social context because it structured parents' delivery of tactile inputs.

Infant Observed Responses to Tactile Stimuli

Infant behaviors and affect were micro-coded second-by-second, based on a coding system designed for the current study. The system was informed by existing coding systems that have been used reliably to code touch and response to touch in parent-child interactions, as well as reactivity to novel stimuli (Feldman & Eidelman, 2003; Feldman et al., 2002; Feldman et al., 2004; Feldman et al., 2003). As the principal aim of the current study was to observe infant responses to tactile stimulation, behaviors and affect were coded only during the delivery of stimulation, that is, only when the infants' hands and feet were being painted, pressed to the paper, and cleaned off with wet wipes. Infant behaviors were coded from 4 categories: direction of gaze (e.g., toward stimulus, away from stimulus), exploring stimulus (e.g., reaching for or manipulating), resistance (e.g., struggling, pushing or pulling away from stimulus), and positive/negative affect. Gaze, exploration, resistance behaviors, and emotional responses have been used in parent-report measures of children's sensory processing to assess infant under- and over-responsiveness, engagement, and attempts to increase or minimize sensory stimulation (e.g., DeGangi & Greenspan, 1989; Dunn & Daniels, 2002; Goldsmith, 1996).

The percentage of time that an infant showed positive and negative affect, showed resistance, and looked away was computed. Following prior research on sensory processing patterns (Dunn & Bennett, 2002), latency (e.g., number of seconds) to explore the stimulus was computed to assess the tendency to quickly seek or to delay exploration of sensory stimulation. Infants' percentage of positive affect, percentage of negative affect, percentage of gaze away, percentage of resistance, and latency to explore were included in analyses. The percentage of negative affect, resistance, and gazing away were standardized and included in analyses as continuous variables. Percentage of positive affect and latency to explore were highly positively skewed. Examining the distribution of the percentage of positive affect revealed that values of 0% occurred at the highest frequency. As a result, two groups were created, one in which infants showed no positive affect (n = 195) and one in which infants showed positive affect at least some of the time (n = 305). Latency to explore was split using the median (7 seconds), which separated infants who explored the stimulus in the first few seconds ($n = 252$) from those who delayed or failed to engage in exploration of the stimulus ($n = 245$).

Parent Behavior during Tactile Interaction

Parent behaviors were micro-coded second-by-second, based on the coding system designed for the current study. The design of this coding scheme was informed by existing coding systems that have been used reliably to code parent physical/vocal engagement and touch patterns (e.g., Feldman et al., 2010). Specifically, mothers' and fathers' behaviors (affectionate touch, game play) were coded second-by-second for each parent. The percentages of time mothers and fathers showed affectionate touch (loving caresses or pokes, hugs, kisses) and game play (game-like motions or vocalizations that are repetitive and rhythmic, including, tickling, funny faces, singing, and making noises) were computed and standardized. Mothers' and fathers' behaviors were combined to create comprehensive measures of the affectionate touch and game play that infants received throughout the task.

Separate teams of undergraduate research assistants were trained to code child and parent behavior. For child coding, seventeen percent of the interactions were double-coded to establish reliability ($n = 87$). Coefficient kappas for each category ranging from .77 to .95 demonstrated high inter-rater reliability. At least seventeen percent of interactions were also double-coded to determine reliability for parent coding ($n = 97$ for mothers; $n = 87$ for fathers), resulting in coefficient kappas for each category ranging from .67 to .83 for mother behavior and .67 to .69 for father behavior.

Parent-Reported Temperament

The Infant Behavior Questionnaire (IBQ) is a 94-item parent-report questionnaire used extensively to assess temperament in infancy (Rothbart, 1981). Caregivers rate, on a 7-point scale in which 1 indicates "Never" and 7 indicates "Always," their infants' responses during feeding, bathing and dressing, play, and daily activities, as well as infants' responses to different soothing techniques. The Activity Level, Distress to Limitations, Distress to Novelty, Duration of Orienting, and Smiling and Laughter subscale were derived from these items and included in the current study. The IBQ shows good internal consistency, with coefficient alphas ranging from .67 to .84 (Rothbart, 1986). In the current sample, alphas for adoptive parents' responses on IBQ scales ranged from .72 to .85. Because mothers have been found to be more accurate reporters of child behaviors (Loeber, Green, & Lahey, 1990; Phares, 1997), we used adoptive mothers' responses to the IBQ to measure infant temperament.

An IBQ scale was considered missing if respondents failed to complete over 20 percent of the items that comprised the scale. The Activity Level, Distress to Limitations, Distress to Novelty, Duration of Orienting, and Smiling and Laughter scales were missing for 16, 15, 51, 23, and 19 participants, respectively. Little's Missing Completely at Random (MCAR; Little, 1988) test suggested that IBQ scale values were observed and missing completely at random.

Data Analysis

Aim 1—Latent Class Analysis (LCA) was used to identify infants' patterns of reactivity to tactile stimulation during parent-infant interaction. The five Flower Print Task variables described above were included in this analysis. Thus, two dichotomous variables (none/at least some positive affect and short/long latency to explore) and three continuous variables (percentages of negative affect, resistance, and gazing away) were included in the LCA. The LCA was conducted in Mplus version 5.1 statistical modeling software (Muthen & Muthen, 2008), using the robust maximum likelihood estimator. To compare the fit of models, the Bayesian information criterion (BIC) and the Vuong-Lo-Mendell-Rubin likelihood ratio test were used.

Aim 2—Correlation analyses and ANOVAs were used to examine the relation between infants' specific behavioral responses and tactile response patterns observed during the Flower Print Task and caregiver report of five dimensions of temperament on the IBQ.

Results

Preliminary Analyses

Means and standard deviations for study variables can be found in Table 1. Correlations were computed across all study variables (Table 2), which revealed small correlations between parent and child behavior during the Flower Print Task. ANOVA and chi square analyses were used to examine sex differences on the dimensional and dichotomous Flower Print Task variables; although evidence for sex differences in sensory processing patterns is mixed (Cheung, & Siu, 2009; Dunn & Westman, 1997; Goldsmith, Lemery-Chalfant, Schmidt, Arneson, & Schmidt, 2007), ANOVA revealed sex differences on one of the five Flower Print Task variables: gazing away ($F(1, 495) = 16.01$, $p < .001$, $f^2 = .03$). An examination of the means indicated that female infants looked away less than male infants (*M:* females = .18; males = .23). Given this difference in behavioral response to tactile stimulation during the Flower Print Task, as well as the correlations between parent and child behavior during the task, differences in sex and parenting behavior based on tactile response patterns were subsequently examined (see below).

Latent Class Analysis

To inform model selection, the fit of models with 2-, 3-, 4-, and 5-class solutions was examined. Following the 2-class solution, the BIC values decreased in the 3- and 4-class solutions, indicating better model fit with the addition of classes. The BIC value for the 5-class model (BIC = 5313.27) was somewhat lower than that of the 4-class model (BIC = 5324.36); however, the Vuong-Lo-Mendell-Rubin likelihood ratio test was significant for the 4-class model but not for the 5-class model, indicating that 4 classes were sufficient ($p < .05$). Furthermore, mean latent class probabilities for each child's most probable class membership suggested that infants were classified appropriately (*M*s for class 1 = .93, class 2 = .91, class 3 = .82, class 4 = .95), and the high entropy value for the 4-class solution also suggested high classification utility (entropy = .82). Two hundred and fifty-one (51%) of the infants were classified in class 1, 124 (25%) in class 2, 100 (20%) in class 3, and 22 (4%) in class 4.

In Figure 1, values (scaled scores and probabilities) for the five Flower Print Task variables included in the LCA are shown for each class.

Class 1 (n = 251) was characterized by below-average levels of negative affect, gazing away, and resistance, as well as a tendency to show positive affect in response to tactile stimulation. Because the infants in Class 1 showed low levels of negative affect or behaviors that could interfere with positive engagement with the stimulus, this class was labeled "Low Reactive."

Class 2 (n = 124) was characterized by high levels of negative affect, but also average levels of gazing away and relatively lower levels of resistance; further, infants in this class were more likely to quickly explore tactile stimuli and less likely to show positive affect. Despite their tendency to quickly explore tactile stimuli, infants in Class 2 showed high reactivity to tactile input, as evidenced by high levels of negative affect, but not heightened attempts to minimize tactile input, such as gazing away or physical resistance. As a result, this class was labeled "Sensory Overreactive."

Class 3 (n = 100) was characterized by average levels of negative affect and gazing away, as well as above average resistance in response to tactile stimulation. Infants in Class 3 also showed a tendency to quickly explore tactile stimuli and respond positively and were, thus, termed "Sensory Seeking."

Class 4 (n = 22) was characterized by high levels of negative affect, gazing away, and resistance, as well as little positive affect and highly delayed or no exploration of tactile stimuli. The group showed behaviors consistent with both over- and under-reactivity to tactile input. As a result, this class was labeled "Mixed Over/Underreactive."

Chi square analysis indicated no sex differences among the four tactile response classes. To determine whether parenting behaviors may have affected infant responses, tactile response pattern class differences in parenting behaviors were examined using ANOVAs, which revealed no significant differences in parents' affectionate touch or game play during the Flower Print Task.

Tactile Response Pattern Differences on Measures of Temperament

As seen in Table 2, preliminary analyses indicated some significant correlations between specific infant behaviors and temperament dimensions, but the magnitude of these correlations was generally small. ANOVAs were used to examine the relation between infants' tactile response patterns identified by LCA of behaviors observed during the Flower Print Task and caregiver report of five dimensions of temperament on the IBQ: Activity Level, Distress to Limitations, Smiling and Laughter, Distress to Novelty, and Duration of Orienting.

There were significant differences among response pattern classes for Activity Level, $F(3, 477) = 2.87$, $p < .05$, $f^2 = .02$, and Distress to Limitations, $F(3, 478) = 7.31$, $p < .001$, $f^2 = .04$, subscales. The Mixed Over/Underreactive class showed significantly higher parent-reported Activity Level (Ms for Low Reactive class = 4.02, Sensory Overreactive class = 4.15, Sensory Seeking class = 4.10, Mixed Over/Underreactive class = 4.48) and Distress to

Limitations (Ms for Low Reactive class = 3.04, Sensory Overreactive class = 3.19, Sensory Seeking class = 3.25, Mixed Over/Underreactive class = 3.72) than the other three classes (Tukey B post-hoc tests, $p < .05$). No tactile response pattern differences were found on any other temperament dimension of the IBQ.

Discussion

Sensory experiences, particularly those involving touch, are critical for infants to communicate and bond with caregivers and to learn about the world (Feldman, et al., 2010; Feldman et al., 2003; Field, 2010). Atypical responses to sensory stimuli (e.g., hypo- or hyper-responsiveness) have been associated with later developmental disabilities, poor motor skills, and difficulties with self-regulation (e.g., Ben-Sasson et al., 2007; DeGangi et al., 1993; Eeles et al., 2013; Mammen et al., 2015).

Although infants' responses to touch develop within the parent-child relationship (Dunn, 2004), most studies of infant sensory processing patterns have relied on parent-report of infants' responses in a broad range of contexts or have used more narrow standardized clinical assessments (e.g., DeGangi & Greenspan, 1989; Dunn & Daniels, 2002). To extend prior research and contribute to understanding the critical role of tactile responding for healthy development, the current investigation assessed infant responses to tactile stimuli during a naturalistic parent-child interaction. Because there is evidence suggesting that infants' behavioral responses to tactile stimulation would be correlated with dimensions of temperament (e.g., Daniels, 2004; Klein et al., 2008), a second aim of the current study was to examine whether the identified tactile response patterns would be related to parent reports of infant temperament.

Latent class analysis of infants' behavioral responses to tactile stimulation, having their hands and feet painted and cleaned off during the Flower Print Task, resulted in classes that were partially consistent with the categories included in the current nosology for sensory processing (Miller et al., 2007); namely, the Sensory Overreactive and Sensory Seeking patterns found in prior research were also identified in the current study. Consistent with prior studies that found a pattern characterized by quick, emotionally intense, and prolonged responses, infants in the Sensory Overreactive group quickly explored tactile stimuli but appeared to be distressed by it. Although prior research has found that sensory overresponsive individuals may show a variety of behavioral responses to sensory input, infants in the Sensory Overreactive class in the current study had a tendency to show negative emotional responses to tactile stimuli but did not resist or avoid looking at tactile stimuli from their parents. It is possible that sensory overresponsiveness in infancy is manifested mainly as emotional distress rather than behavioral attempts to avoid or minimize sensory input.

In contrast, while infants in the Sensory Seeking group also quickly explored tactile stimuli, they expressed high levels of positive affect and high levels of physical resistance behaviors (e.g., struggling, pushing or pulling away from stimulus) during the Flower Print Task. This is consistent with prior research on children who are more likely to seek sensory input through a range of heightened affective and behavioral responses, such as by exhibiting high levels of positive affect in response to sensory stimulation and becoming resistant (e.g., temper tantrums, aggressive behavior) when sufficient sensory input is not achieved (Dunn, 1997; Miller et al., 2007). Resistance behaviors could have been amplified for the Sensory Seeking infants in the current study because parents held them during the task and controlled the delivery of tactile stimuli.

Although a distinct Sensory Underreactive pattern was not identified, possibly because lack of responsiveness to sensory stimuli is more prevalent in samples of children with developmental disabilities (Tomchek & Dunn, 2007), a small group of infants with mixed responses to tactile stimulation was found. Infants in the Mixed Over/Underreactive group were highly negative and resistant to tactile stimuli during the Flower Print Task, consistent with sensory overresponsivity, but also showed very delayed or no exploration of the stimulus, consistent with sensory underresponsivity. Infants who show both over- and under-responsiveness to tactile stimuli may have inconsistent, disorganized sensory experiences, suggesting risk for atypical development (Bron, van Rijen, van Abeelen, & Lambregtse- van den Berg, 2012). Of note, a similar pattern of heightened avoidance and limited exploration of sensory input was found in a study of toddlers with Autism Spectrum Disorder (Ben-Sasson et al., 2007). Together, findings suggest that infants in the Mixed Sensory Over/Underreactive group may be at risk for atypical development.

Although there is limited information about the prevalence of specific sensory processing patterns in normative samples, particularly during infancy, the distributions of infants among the latent class groups in the current study were consistent with prior research on older children's responses to sensory stimuli (Carter, Ben-Sasson, & Briggs-Gowan, 2011; Tomchek & Dunn, 2007), including the small Mixed Over/Underreactive class (Ahn, Miller, Milberger, & McIntosh, 2004; Gouze, Hopkins, LeBailly, & Lavigne, 2009; ICDL, 2005).

Together, the characteristics and distributions of the tactile response patterns yielded from the LCA in the current study support the current nosology of sensory processing (Miller et al., 2007) by providing evidence that comparable patterns may be observed within a large, normative sample of young infants when assessing responses only to tactile stimulation during a social interaction.

To explore child characteristics that may be correlates of infants' tactile response patterns during parent-child interaction, based on prior research (Daniels, 2004; DeSantis et al., 2011; Klein et al., 2008; O'Boyle & Rothbart, 1996), we examined relations between infants' tactile response patterns and caregiver report of five dimensions of temperament. As a whole, the sample of infants showed some modest correlations between affective responses to tactile stimulation and temperamental responses in their daily lives, but in terms of the identified tactile response patterns, only the Mixed Over/Underreactive class exhibited significant differences in temperament. Specifically, infants in the Mixed Over/Underreactive class were rated by their parents as showing higher distress to limitations and higher activity levels, and these differences were consistent when controlling for parent behavior during the Flower Print Task. In contrast to prior research on the relation between sensory processing patterns and temperament in infants and young children (Daniels, 2004;

DeSantis et al., 2011; Klein et al., 2008; O'Boyle & Rothbart, 1996), no class differences in any other dimension of temperament emerged.

There could be methodological explanations for inconsistencies between the findings of prior studies and the current findings regarding links between sensory processing patterns and measures of temperament. For example, most studies have examined the association between sensory processing patterns and dimensions of temperament using parent-report measures of both constructs, which may reflect method variance. In other work, low convergence across parent ratings and observational measures of temperament has also been reported (e.g., Gartstein & Marmion, 2008), suggesting the limited associations found between tactile sensory processing patterns and dimensions of temperament in the current study may be due to the use of different methods for assessing the two constructs. Notably, our findings were consistent with the only prior study to examine the relation between observed sensory processing patterns and parent-reported temperament, in which DeGangi and Greenspan (1988) found that infants described as "difficult," or prone to distress, by parents were observed to be more reactive when exposed to sensory stimuli by an examiner.

Besides methodological issues, there are many conceptual questions regarding the relation between sensory processing patterns and temperamental dimensions. Although some models propose that sensory reactivity is a dimension of temperament (e.g., Rothbart, Ahadi, Hershey, & Fisher, 2001) and both constructs have been proposed as early indicators of disordered development (Bron et al., 2012; DeSantis et al., 2011), the constructs may be related but independent. Indeed, whereas sensory processing patterns appear to show little change across early development (e.g., sensory overresponsivity; Ben-Sasson, Carter, & Briggs-Gowan, 2010), dimensions of temperament show normative increases across early childhood (e.g., difficult temperament, fear; Brooker et al., 2013; Wood, 2011). Future research examining the relation between these two constructs over time may increase our understanding of the contribution each makes to disordered outcomes.

Limitations

Various limitations should be considered. First, although the parents and infants participated in a structured task and we measured and controlled for common and relevant parenting behaviors, we had no control over or way to assess specific types of subtle touch provided by parents (e.g., light touch versus firm touch), and it is possible that infants responded differently to specific types of tactile stimulation. Further, infants' responses to tactile stimulation were measured during a single interaction task, and future research could examine how infants respond to other types of sensory stimulation (e.g., olfactory, auditory) or interaction (e.g., with a stranger). Second, the small size of the Mixed Over/Underreactive class may pose problems for its validity in the current sample, although if this class represents an at-risk group, the low rate is similar to that in other research (Ahn, Miller, Milberger, & McIntosh, 2004; Gouze, Hopkins, LeBailly, & Lavigne, 2009; ICDL, 2005). Future research examining links between the Mixed Over/Underreactive class and later regulatory outcomes will be necessary for understanding whether and how this subset differs meaningfully from the rest of the population. For instance, research suggests that a mixed pattern of underresponsiveness and overreactivity to (e.g., avoidance) sensory input may be characteristic of Autism Spectrum Disorder (Ben-Sasson et al., 2007). Third, although latent classes indicative of tactile response patterns were generally consistent with findings from prior studies, no independent measure of sensory processing patterns (e.g., parent report) was available to validate the classes. Fourth, although there was strong justification for investigating the relation between observed tactile response patterns and temperament, the limitations of examining differences between groups with unequal and small sample sizes should be taken into account.

Conclusions

To our knowledge, the current study is the first to examine infants' tactile response patterns during a parent-child interaction, and results were largely consistent with existing models of sensory processing patterns identified from parent reports (Miller et al., 2007). By measuring infant tactile response patterns within parent-child interaction, this investigation has contributed to literature on the measurement of sensory processing and has laid the groundwork for future research examining mechanisms through which infants' sensory processing interacts with the social environment to affect developmental outcomes. For instance, future research with the current sample could identify genetic, prenatal, and parenting factors that may affect pathways between infant tactile response patterns and later developmental outcomes. Indeed, such research could help to clarify the role sensory responses may play in child social-emotional and regulatory development.

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Highlights

- Four tactile response patterns identified during parent-child interaction.
- Patterns are consistent with those identified from parent-report.
- Findings support current nosology for sensory processing.
- Pattern of over- and under-reactivity may suggest risk for atypical development.

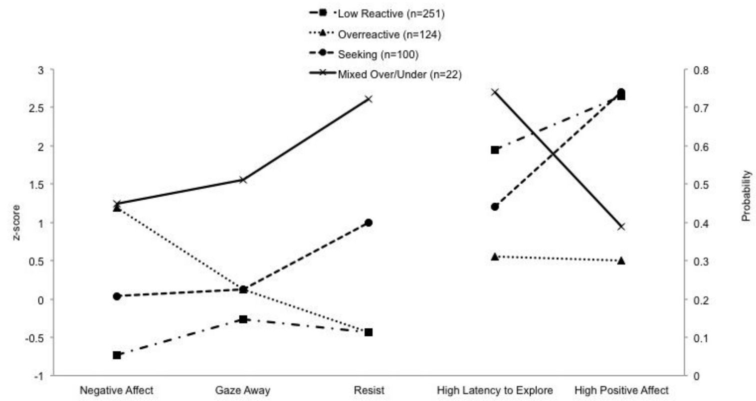

Figure 1.

Means and Probabilities of Flower Print Task Variables by Class. This figure shows the values (means and probabilities) for the five Flower Print Task variables included in the LCA for each of the tactile response pattern classes, illustrating how classes differed in their responses to tactile stimulation during the Flower Print Task.

Table 1

Descriptive Statistics for Temperament and Tactile Response Variables.

Variable	*N*	Range	Mean	*SD*
IBQ				
Activity Level	481	2.00-6.36	4.09	.75
Distress to Limitations	482	1.13-5.50	3.15	.72
Distress to Novelty	446	1.00-4.64	2.42	.62
Duration of Orienting	474	1.18-6.36	3.49	.92
Smiling and Laughter	478	2.87-6.93	5.11	.77
Flower Print Task				
Percent Child Positive	497	.00-.54	.05	.08
Percent Child Negative	497	.00-1.00	.40	.28
Percent Child Gaze Away	497	.00-.91	.21	.13
Percent Child Resist	497	.00-.35	.07	.06
Child Latency to Explore (seconds)	497	1.00-287.00	24.09	41.34
Percent Mother Play	497	.00-.38	.04	.01
Percent Father Play	497	.00-.33	.03	.04
Percent Mother Affection	497	.00-.15	.01	.02
Percent Father Affection	497	.00-.11	.01	.02

Table 2

Correlations Among Study Variables.

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Activity Level	--										
2. Distress to Limitations	.35**	--									
3. Distress to Novelty	.20**	.32**	--								
4. Duration of Orienting	−.07	−.17**	.02	--							
5. Smiling and Laughter	.04	−.14**	−.14**	.35**	--						
6. FP-Positive	.00	.04	−.07	.04	.13**	--					
7. FP-Negative	.12*	.16**	.06	−.01	−.01	−.28**	--				
8. FP-Away	.03	.10*	.04	.00	−.08	−.12**	.26**	--			
9. FP-Resist	.11*	.21**	.08	.06	−.03	−.03	.21**	.29**	--		
10. FP-Explore	.08	.06	.02	−.05	−.06	−.02	−.12**	.10*	.06	--	
11. FP-Parent Play	.11*	.08	−.02	.06	.07	.18**	.07	.03	.03	.00	--
12. FP-Parent Affection	−.01	.01	.06	−.02	−.01	−.01	.11*	.08	.03	−.01	.16**

Note.

* $p < .05$.

** $p < .01$. FP = Flower Print Task