EFFECTS OF INFANT AND MATERNAL SENSORY PROCESSING ON INFANT FUSSING, CRYING, AND SLEEP

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ABSTRACT: This study investigated the effects of infant and maternal sensory processing on sleep, fussing, and crying in a sample of 55 firstborn, 4- to 7-month-old infants and their mothers. Mothers completed self-report questionnaires to assess maternal and infant sensory processing styles and a 4-day diary of infant behavior, including sleep, fussing, and crying. Higher levels of infant Sensation Avoiding were associated with less sleep, more fussing, and more crying whereas higher levels of Sensory Sensitivity were associated with less sleep and more fussing. The positive association between infant Sensation Avoiding and crying was strengthened by lower levels of Low Registration in mothers. The effect of infant Sensory Sensitivity on reducing total sleep also was strengthened by lower levels of maternal Low Registration. Assessment of infant sensory processing as well as the moderating effect of maternal sensory processing on the relationship between infant sensory processing and infant regulatory capacities need to be considered when assessing and designing interventions for families in which infant regulation is problematic.

RESUMEN: Este estudio investigó los efectos que los procesos sensoriales del infante y maternos tienen en el sueño, los quejidos y el llanto en un grupo muestra de 55 infantes primerizos de cuatro a siete meses de edad y sus madres. Las madres completaron cuestionarios de auto-reporte para evaluar los estilos de procesos sensoriales maternos y del infante, y un diario de 4 días acerca de la conducta del infante, incluyendo el sueño, los quejidos y el llanto. Altos niveles del proceso de Evitar Sensaciones en el infante fueron asociados con dormir menos, quejarse y llorar más, y mientras tanto altos niveles de Sensibilidad Sensorial fueron asociados con dormir menos y quejarse más. La positiva asociación entre el proceso de Evitar Sensaciones del infante y el llanto fue reforzada por más bajos niveles de Bajos Registros en las madres. El efecto de la Sensibilidad Sensorial del infante en la reducción de la totalidad de dormir fue también reforzado por más bajos niveles de Bajos Registros maternos. Cuando se evalúen y diseñen intervenciones para familias en las cuales la regulación del infante es problemática, se necesita considerar la evaluación de los procesos sensoriales del infante, así como también el efecto moderador que los procesos sensoriales maternos tienen sobre la relación entre los procesos sensoriales del infante y sus capacidades regulatorias.

RÈSUMÈ: Cette étude a porté sur les effets du traitement sensoriel du bébé et maternel sur le sommeil, les pleurnicheries et les pleurs chez un échantillon de 55 premiers-nés, âgés de quatre à sept mois et leurs mères. Les mères ont rempli un questionnaire d'auto-évaluation afin d'évaluer les styles de traitement sensoriel maternel et du bébé et ont aussi tenu un journal de comportement du bébé, incluant le sommeil, les pleurnicheries et les pleurs. Des niveaux plus élevés d'Evitement Sensoriel du bébé étaient liés à moins de sommeil et à plus de pleurnicheries. Le lien positif entre l' Evitement Sensoriel et les pleurs était renforcé par des niveaux plus bas de stratégies et comportements d'auto-régulation Low Registration chez les mères. L'effet de la Sensibilité Sensorielle du bébé sur la réduction du sommeil total était aussi renforcé par des niveaux plus bas de stratégies et comportements d'auto-régulation Low Registration chez les mères. L'évaluation du traitement sensoriel du bébé, ainsi que de l'effet modérateur du traitement sensoriel maternel sur la relation entre le traitement sensoriel du bébé et les capacités régulatrices du bébé doit être tenue en compte lorsqu'on évalue ou lorsqu'on conceptualise des interventions pour des familles dans lesquelles la régulation du bébé est problématique.

ZUSAMMENFASSUNG: Diese Studie untersuchte die Auswirkungen der kindlichen und mütterlichen sensorischen Verarbeitung auf den Schlaf, das Unwohlsein und Weinen in einer Stichprobe von 55 vier bis sieben Monate alten Erstgeborenen und ihren Müttern. Die Mütter vervollständigten Selbstbeurteilungsfragebogen um die mütterlichen und kindlichen sensorischen Verarbeitungsstile zu bewerten und führten 4 Tage Tagebuch über das Verhalten der Säuglinge einschließlich zu Schlaf, Unwohlsein und Weinen. Ein höheres Level an kindlicher Wahrnehmungsvermeidung war mit weniger Schlaf, mehr Unwohlsein und mehr Weinen verbunden, während ein höheres Level an sensorischer Empfindlichkeit mit weniger Schlaf und mehr Unwohlsein verbunden war. Der positive Zusammenhang zwischen der kindlichen Wahrnehmungsvermeidung und dem Weinen wurde von geringer

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mütterlicher Registrierung der Signale verstärkt. Der Effekt von kindlicher sensorischer Empfindlichkeit auf die Verringerung des Gesamtschlafs wurde auch von geringer mütterlicher Registrierung verstärkt. Die Einschätzung der kindlichen sensorischen Verarbeitung, sowie der Moderatoreffekt der mütterlichen sensorischen Verarbeitung auf die Beziehung zwischen der kindlichen sensorischen Verarbeitung und den kindlichen regulatorischen Fähigkeiten müssen bei der Beurteilung und Gestaltung von Interventionen für Familien, in denen die kindliche Regulation problematisch ist, beachtet werden.

ABSTRACT: 抄録:この研究は、55組の第1子、月齢4~7ヶ月とその母親というサンプルにおいて、睡眠、むずかり、および泣きについての、乳児と母親の感覚処理sensory processingの影響を調査した。母親は、母親と乳児の感覚処理スタイルを評価するために、自己報告式の質問紙に記入した。そして睡眠、むずかりと泣きを含む4日間の日記を記入した。高い水準の乳児のSensation Avoidingは、睡眠がより少なく、むずかりがより多く、よりたくさん泣くことと関連していた。そして高い水準のSensory Sensitivityは、睡眠がより少なく、むずかりがより多いことと関連していた。乳児のSensation Avoidingと泣くことの間の正相関は、母親の低い水準のLow Registrationによって強化された。乳児のSensory Sensitivityが全睡眠時間を減らす影響も、母親の低い水準のLow Registrationによって強化された。乳児の感覚処理を評価することは、乳児の感覚処理と乳児の調節能力との間の関係性に、母親の感覚処理が与える介在する影響とともに、乳児の調節が問題となる家族のための介入を評価してデザインするときに、考慮する必要がある。

摘要: 這項研究調查了嬰兒和母親的感官處理對睡眠、激動和哭泣的影響,研究樣本是55名第一個出生、四至七個月大的嬰兒和他們的母親。母親完成了自我報告的問卷,以評估母親和嬰兒的感官處理方式以及4天嬰兒行為的日記,包括睡眠、激動和哭泣。較高的嬰兒感官回避(Sensation Avoiding)與較少睡眠、較多激動和較多哭泣有關,較高的感官靈敏度(Sensory Sensitivity)則與較少睡眠和較多激動有關。母親較低察覺力(Low Registration)加強了嬰兒感官回避和哭泣之間的正相關性。母親較低察覺力亦加強了嬰兒感官敏感度降低睡眠總數的效果。研究者在嬰兒調控有問題的家庭,作出評估和設計干預措施時,需要考慮嬰兒感官處理的評估,以及母親感官處理如何調節嬰兒感官處理和嬰兒調控能力之間的關係。

ملخص: تحققت هذه الدراسة من آثار الحسية للرضع والأمهات والمعالجة بالنسبة الى النوم، والقلق والبكاء في عينة من 55 أول طفل رضيع، من اربعة الى سبغة أشهر من العمر وأمهاتهم. الأمهات أكملن الاستبيانات للتقرير الذاتي لتقييم أساليب المعالجة الحسية عند الأمهات والرضع ومذكرات 4 أيام من السلوك بما في ذلك النوم، والاضطراب والبكاء عند الرضع. المستويات الأعلى من تجنب الإحساس عند الرضع ارتبطت مع قلة النوم، وكثرة البكاء والاضطرابات، وبينما ارتبطت مستويات أعلى من الحساسية الحسية مع قلة النوم ومزيد من القلق. وتم تعزيز علاقة إيجابية بين الإحساس عند الرضع تجنب البكاء مع مستويات أدنى من انخفاض في التسجيل عند الأمهات. تم تعزيز تأثير الحساسية الحسية عند الرضع على الحد الكلي من النوم أيضا مع مستويات أدنى من التسجيل عند الأمهات. تقييم المعالجة الحسية للرضع، فضلا عن أثر ملطف للمعالجة الحسية عند الأمهات على العلاقة بين المعالجة الحسية للرضع والقدرات التنظيمية ، والحاجة إلى أخذها في الاعتبار عند تقييم وتصميم التدخلات للأسر التي تعاني من إشكالية التنظيم للرضع .

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Longitudinal research has demonstrated that the capacity to regulate affect and behavior in infancy is an important factor contributing to childhood and adolescent psychosocial adjustment (Calkins & Fox, 2002; Dale et al., 2011; DeGangi, Breinbauer, Roosevelt, Porges, & Greenspan, 2000). The infant's capacity to self-regulate bodily states and to use their behaviors to self-soothe and elicit soothing from caregivers has important developmental implications. Regulatory capacities are thought to be important in allowing infants to cope with unpredictable and changing environmental stimuli (Dale et al., 2011).

Symptoms considered indicative of a regulatory disorder of infancy include excessive fussing and crying, difficulties in being soothed or self-soothing, sensory sensitivity, and difficulties with sleep onset, maintenance, or insufficient total sleep (Calkins & Fox, 2002; Dale et al., 2011; DeGangi et al., 2000). The aims of this study were to determine the interaction between infant sleep, fussing, and crying and to identify the relationship between infant and maternal sensory processing.

SLEEP

Infant sleep tends to become organized into an increasingly nocturnal pattern at around 3 months of age (Spruyt et al., 2008). In a review of problem behaviors associated with infant sleep disturbance, France and Blampied (1999) reported associations with increased crying and irritability, and concluded that parents of sleep-disturbed infants use less consistent and more stimulating bedtime rituals. Lam, Hiscock, and Wake (2003) found that sleep problems in a sample of 3- to 4-year-old children, which had persisted since infancy, were associated with higher levels of internalizing and externalizing behavior and somatic problems. In mothers with no past history of depression, infant sleep problems have been found to predict postnatal depression and poorer physical health (Martin, Hiscock, Hardy, Davey, & Wake 2007). Velluti (1997) concluded that sleep/wake cycles and sleep behavior depend on a bidirectional relationship between sensory input and the central nervous system (CNS), with activation of sensory systems through stimulation and, conversely, reduction of sensory stimulation both used to soothe infants to sleep (Velluti, 1997). Similarly, methods of soothing fussing and crying in infants vary from those which aim to decrease sensory stimulation, such as swaddling and leaving the infant alone in a quiet room, to those which attempt to increase controlled stimulation, such as through the use of white noise, jiggling, car or pram rides (McRury & Zolotor, 2010), or holding and carrying (Abdulrazzaq, Kendi, & Nagelkerke, 2009).

FUSSING AND CRYING

Excessive infant fussing and crying is associated with negative infant and family outcomes such as shortened breastfeeding duration (Howard, Lanphear, Lanphear, Eberly, & Lawrence, 2006), heightened risk of maternal depression (Salisbury et al., 2012; Wake et al., 2006), maternal anxiety, parenting stress, lowered sense of parenting self-efficacy (Megel, Wilson, Bravo, McMahon, & Towne, 2011), and marital stress (Levitzky & Cooper, 2000). The fatiguing effect on mothers of excessive infant crying has been shown to accumulate and impair empathic care, further exacerbating infant crying (Kurth, Kennedy, Spichiger, Hösli, & Zemp Stutz, 2011). Of greatest concern is that infant crying is a well-established, significant risk factor for infant physical abuse such as shaking, smothering, and slapping, with the risk of abuse rising steadily over the first 6 months (Jerome & Liss, 2005; Reijneveld, van der Wal, Brugman, Hira Sing, & Verloove-Vanhorick, 2004). Beyond infancy, a history of infant crying, fussing, and sleep problems has been shown to predict enduring maternal depression, parenting stress, and child behavior problems (Chronis-Tuscano et al., 2009; Hemmi, Wolke, & Schneider, 2011; Wake et al., 2006).

Agreement about the etiology and best-practice treatment for excessive infant crying is not well-established. Parents receive conflicting treatment advice from medical practitioners, maternal child health nurses, and inpatient early parenting centers (Douglas & Hiscock, 2010). Associations have been demonstrated between infant sensory processing and regulation, with low sensory threshold, or a tendency to process and react to lower levels of stimuli, being predictive of irritability and more difficulty soothing (DeSantis, Harkins, Tronick, Kaplan, & Beeghly, 2011). The present study will examine the relationship between infant sensory processing and infant fussing, crying, and sleep, and investigate the impact of maternal and infant sensory processing on infant regulation.

Immaturity of the infant's CNS is proposed to result in difficulties downregulating from a crying state to a sleep state, despite fatigue. It is proposed that these infants have a greater need for caregiver support to reduce their arousal; however, the signals that they emit are less predictable and therefore difficult for the caregiver to interpret and respond to effectively. The implications for treatment are that mothers who are able to modify vestibular, auditory, tactile, and visual stimuli contingent upon their infant's arousal will be more effective in soothing an irritable infant and avoiding a negative feedback cycle. Factors intrinsic to the mother that may impede her capacity to do this effectively (Keefe, 1988) are a focus of this research.

PERSISTENT REGULATORY PROBLEMS

A significant proportion of infants continue to exhibit signs of regulatory disorder, such as excessive fussing, crying, and sleep difficulties—frequently described as colic–beyond 3 months (Wurmser, Laubereau, Hermann, Papoušek, & von Kries, 2001). Rautava, Lehtonen, Helenius, and Sillanpää (1995) reported ongoing problems with sleeping and temper tantrums at age 3 years and that families whose infants had previously had colic expressed more dissatisfaction with activities of family life than did a non-colic group. Wolke, Rizzo, and Woods (2002) conducted 4-year follow-up investigations of children who, as 8- to 11-month-old infants, were described as fussy, difficult-to-soothe infants, with problems in sleeping, feeding, transitions between activities, and coping with sensorimotor challenges. In contrast to a control group, at age 4 years, those with regulatory problems in infancy had perceptual, language, sensory integrative, emotional, and behavioral problems, including hyperactivity and reduced attention span (Wolke et al., 2002). Based on a meta-analysis of longitudinal studies, Hemmi et al. (2011) concluded that children with previous regulatory problems, defined as excessive crying beyond 3 months of age, and feeding and sleeping problems were at significantly greater risk of behavior problems such as internalizing, externalizing, hyperactivity, and attention and concentration deficits, as compared to controls. Risk increased for those who had suffered from multiple regulatory problems (Hemmi et al., 2011).

SENSORY PROCESSING

Sensory processing theory, as described by Dunn (1997), provides further explanation of the role of the CNS in influencing infant regulatory behaviors. She theorized that the CNS modulates processing of sensory information via a continuous interaction between habituation and sensitization to stimuli. She also proposed that an individual's neurological threshold might be seen on a continuum indicating higher or lower levels of stimuli required by the nervous system to enable the individual to notice or react to stimuli. A high threshold indicates a sensory processing system that is more habituated to stimuli. Individuals who are closer to this extreme will only notice or react to higher levels of a stimulus. A low threshold indicates that an individual notices stimuli more easily, at lower levels of input, or is sensitized to stimuli. The *x* axis of Dunn's model reflects the behavioral response continuum, which is the manner in which individuals respond to their threshold for stimulation. The behavioral response can be understood as an effort toward self-regulation. At one extreme, behavior may be in accordance with the threshold, or relatively passive in manner. At the other extreme, the behavioral response will be an active attempt to counteract the threshold (see Figure 1 for Dunn's model).

Atypical sensory processing has been demonstrated in children with early fuss/cry difficulties (DeSantis, Coster, Bigsby, & Lester, 2004; Wolke et al., 2002). Infants depend on their caregivers to accurately interpret their need for support in receiving, processing, and avoiding excessive or aversive sensory input (Papoušek, 2011). When an infant's capacity to attenuate arousal through self-soothing or the effective use of the soothing actions of caregivers is inadequate, it is thought to contribute to irritability, sleep and feeding problems, hyperactivity, and/or restlessness (DeSantis et al., 2004; Dollberg, Feldman, Keren, & Guedeney, 2006; Schmid, Schreier, Meyer, & Wolke, 2011).

	Behavioral Responses/Self-Regulation Continuum	
Neurological Threshold	PASSIVE	ACTIVE
HIGH THRESHOLD (Habituation)	Low Registration	Sensation Seeking
LOW THRESHOLD (Sensitization)	Sensory Sensitivity	Sensation Avoiding

FIGURE 1. Dunn's model of sensory processing. Reprinted from Dunn (1997).

ADULT SENSORY PROCESSING

Parents vary in their level of attunement to their infants' signals (Feldman & Eidelman, 2009). This variation may be affected by infant, parent, and interactive factors as well as by external environmental stressors. Where mutually reinforcing cycles of escalating arousal develop within the infant–parent dyad, instead of emotionally attuned, supportive behaviors, parents have been shown to respond with hyperaroused, vigorous, rough handling, and overstimulation (Ziegler, Wollwerth de Chuquisengo, & Papoušek, 2008). On the other hand, parents with a high threshold, who tend not to notice stimuli at lower levels, may be relatively disengaged from their infant's signals and fail to notice a need for more, less, or different stimulation.

Understanding of sensory preferences in mothers may help explain inadequate attunement and behavioral synchrony in the infant–parent dyad, particularly where persistent regulatory problems exist. Poorly synchronized infant–maternal behavior may be the result of mismatched sensory receptivity and responses. In terms of infant regulatory development, particular sensory awareness and response styles in parents may be a better fit than are others when combined with particular infant sensory awareness and response profiles. In support of this proposal, research has demonstrated that maternal tactile stimulation when infant gaze is averted (a withdrawal, or sensation-avoiding behavioral response) is associated with higher maternal and infant cortisol (Feldman, Singer, & Zagoory, 2010). Higher cortisol levels suggest that the lack of synchrony is stressful for both mother and infant and may lead to an exacerbation of mutual dysregulation.

At the time of writing, there was no known research investigating the possible contribution of maternal sensory processing, according to Dunn's (1997) model, to infant regulation. The measurement of sensory processing across a range of sensory domains and according to sensory threshold and behavioral response in mothers of infants, using the Adolescent/Adult Sensory Profile (AASP; Brown, Tollefson, Dunn, Cromwell, & Filion, 2001), would contribute to the understanding of the role of maternal sensory processing in infant caregiving.

Jerome and Liss (2005) used the AASP to study the impact of adult sensory processing on adult attachment and coping in a nonclinical population. They found that Sensory Sensitivity was positively associated with relationship anxiety, Sensation Avoiding was positively associated with relationship avoidance, Sensory Seeking was positively associated with secure attachment, and Low Registration was positively correlated with both relationship anxiety and relationship avoidance. These results may be useful in understanding maternal responses to their infants. Where an infant with a low neurological threshold (more Sensory Sensitive or Sensation Avoiding) needs more sensitive and responsive maternal support to prevent him or her from becoming overwhelmed, to downregulate from a fussing or crying state and to assist with sleep, the awareness and responses of the mother are likely to be more crucial.

The nature of the interaction between maternal sensory processing and responsiveness, and infant regulation when the infant has greater need for sensory processing support, is unknown. No evidence basis currently exists for speculation about the nature or direction of moderation by maternal sensory processing on infant regulation. Such knowledge may benefit mothers and professionals by assisting them in managing infant regulatory difficulties.

This study sought to explore the relationship between infant sensory processing and regulatory factors, including fussing, crying, and sleep difficulties beyond the usual 3-month colic period, in 4- to 7-month-old infants. It also aims to fill a gap in the existing literature by investigating whether maternal sensory processing has a moderating influence on this relationship.

We predicted that low sensory thresholds in infants would be associated with more regulatory difficulties. In particular, it was predicted that more fussing and crying and less sleep would be associated with both higher levels of infant Sensory Sensitivity and higher levels of infant Sensation Avoiding. The possible moderating effect of maternal sensory processing on the strength of the relationship between infant sensory processing and amount of fussing, crying, and sleep per day also was investigated.

METHOD

Participants

A total of 94 mothers expressed interest in participation. Of these, 31 did not continue for the following reasons: no response to

follow-up attempts ($n = 9$), declined or withdrew ($n = 10$), did not meet inclusion criteria ($n = 7$), and incomplete data ($n = 5$). Thirteen participants were recruited through two early parenting centers providing day patient, residential stays, or consultancy for sleep, feeding, and behavior problems in infants and young children. The remaining 50 were recruited through Maternal Child Health Centres. Eight participants returned incomplete diaries or failed to return the diary. The current analyses were restricted to the final sample of 55 participants who returned completed diaries of infant regulatory behavior.

Inclusion criteria required that infants be the firstborn child of their mother, from singleton pregnancies, aged between 4 and 7 months (17–32 weeks), healthy at the time of assessment, born at full-term (38–42 weeks), and of normal birth weight (at least 2500 g), with no diagnosed medical complications or known neurological conditions. Infants were assessed for these criteria on the basis of the prior knowledge of nurses assisting with recruitment or mothers self-selected on the basis of reading the participant requirements in the written information provided and then confirmed in initial telephone contact with the research team.

Of the 55 infants, 29 were male and 26 were female, with a mean infant age of 23.07 ($SD = 3.50$) weeks. No significant gender differences were found in terms of age or the variables under investigation; therefore, infant data were combined for all statistical analyses. Mean age of the mothers was 32.45 ($SD = 5.95$) years. Twelve of the 55 mothers (22%) were of ethnic origins other than Anglo-Saxon, including Indian, Middle Eastern, Japanese, Chinese, African, Latin American, and Polish. Fifty-three of the mothers reported living with a partner, and 2 were single. All 55 mothers had completed Year 12 or equivalent of education ($M = 14.82$, $SD = 3.36$).

Mothers and infants were recruited through the early parenting centre and the consultancy service in an attempt to include a proportion of the sample with more regulatory difficulties.

Measures

The AASP (Brown et al., 2001) was used to measure maternal sensory processing profiles. The AASP is a 60-item self-report questionnaire used for measuring sensory processing preferences for people aged 11 years and older. Participants indicate on a 5-point scale the frequency with which they respond to various sensory experiences, from 5% of the time (*Almost Never*), which is scored 1, to 95% of the time (*Almost Always*), which is scored 5. The AASP can be scored in a number of ways. For this study, scores were analyzed according to the four quadrants comprising Dunn's (1997) model of sensory processing. The model describes four different sensory processing tendencies, arising from a neurological threshold continuum from low to high and a behavioral response continuum ranging from accordance to counteract. Each quadrant results from the interaction of the two continua. The first quadrant, Sensory Sensitivity, is characterized by behaviors in response to a low neurological threshold. High scores on these items indicate a high level of Sensory Sensitivity and may manifest in distractibility due to difficulty screening out stimuli to focus on the most important stimuli, and discomfort with many sensory experiences. The second quadrant, Sensation Avoiding, represents counteracting behaviors for a low neurological threshold, such as infants who cannot tolerate higher levels of visual stimulation. The third quadrant, Low Registration, reflects responses to a high neurological threshold, with disregard of or slow response to sensations. The fourth quadrant, Sensation Seeking, involves responses that counteract a high neurological threshold, such as infants who seek out high levels of sounds and movement. Each quadrant is comprised of 15 items, and high scores indicate a high level of the sensory processing characteristic for each quadrant. For the present study, scores from the AASP were used as continuous measures. The Adolescent/Adult Sensory Profile has demonstrated convergent validity with skin conductance responsivity and trials to habituation (Brown et al., 2001). Acceptable reliability has been reported for the four quadrants, ranging from Cronbach's $\alpha = .64$ to .78 (Pearson Education, 2008). For the present study, Cronbach's $\alpha = .72$ for the complete scale, $\alpha = .66$ for the Sensory Sensitivity quadrant scores, $\alpha = .76$ for the Sensation Seeking quadrant, $\alpha = .78$ for the Sensory Avoiding quadrant, and $\alpha = .82$ for the Low Registration quadrant. The AASP also can be scored categorically, with the numerical scores grouped according to: *much less than most people*; *less than most people*; *similar to most people*; *more than most people*; and *much more than most people*. The items also may be group according to sensory modality: taste/smell processing; movement processing; visual processing; touch processing; activity level; and auditory processing (Brown & Dunn, 2002).

The Infant/Toddler Sensory Profile (ITSP; Dunn & Daniels, 2002), a 36-item caregiver report questionnaire for infants from birth up to and including 6 months of age, was used to measure infant sensory functioning. Items describe responses to stimulation in five sensory categories: general, auditory, visual, tactile, and vestibular, which are combined to create the four quadrant scores, similar to the AASP. Dunn's (1997) model of sensory processing is the basis for the quadrant scores, which are divided into Low Registration, Sensation Seeking, Sensory Sensitivity, and Sensation Avoiding. The ITSP has demonstrated item and quadrant internal consistency, with a Cronbach's α coefficient of .17 to .83 for infants from birth to 6 months and .42 to .86 for children ages 7 to 36 months (Dunn & Daniels, 2002). Reliability coefficients for the present sample were: full scale Cronbach's $\alpha = .67$, Low Registration $\alpha = .31$, Sensation Avoiding $\alpha = .51$, Sensation Seeking $\alpha = .52$, and Sensory Sensitive $\alpha = .76$.

The direction of scores on the ITSP was reversed to allow consistency with the scoring of the AASP and so that high scores on both adult and infant sensory processing measures indicate high levels of the characteristic described by each quadrant.

Infant regulatory behaviors were assessed by means of the Baby's Day Diary (Barr, Kramer, Boisjoly, McVey-White, & Pless, 1988). Duration (in minutes) of fussing, crying, and sleep was

recorded by mothers over 4 consecutive 24-hr days and returned by mail. Barr et al. (1988) reported moderately strong correlations between data from voice-activated audio recordings of infant negative vocalizations and parent report using the Diary, suggesting that it is a valid tool for assessing infant behavior Mothers recorded their infant's duration of fussing, crying, being awake and content, sleeping, feeding, and caregiver comforting behaviors, in 5-min blocks, at regular intervals throughout the day, and overnight behaviors as soon as possible after waking in the morning. Fussing and crying were examined both as separate variables and added together to create a combined variable for statistical analysis. The literature on infant regulatory problems commonly refers to fussing and crying interchangeably or combined, as an indicator of irritability, colic, or an unsettled state (Wake et al., 2006).

TABLE 1. *Infant Regulatory Characteristics (*N = *55)*

		95% CI	
	M (*SD*)	Minimum	Maximum
Sleep	817.91 (79.98)	646.25	1012.50
Crying	33.83 (24.52)	0.00	97.50
Fussing	82.96 (48.37)	0.00	223.75
Fussing & Crying	116.79 (59.81)	0.00	257.50

Note. All values represent average minutes per day, calculated over the 4 days recorded in the Baby's Day Diary (Barr et al., 1988). Upper and lower limits for the sample are represented by minimum and maximum, respectively.

TABLE 2. *Descriptive Statistics of the Infant (ITSP) and Maternal (AASP) Sensory Processing Variables (*N = *55)*

Scale	Sensory Processing	*M*	*SD*	95% CI
ITSP	Low Registration	47.93	4.14	[46.81, 49.05]
	Sensation Seeking	9.27	2.08	[8.71, 9.83]
	Sensory Sensitivity	46.93	6.15	[45.26, 48.59]
	Sensation Avoiding	21.65	2.20	[21.05, 22.25]
AASP	Low Registration	30.90	6.76	[29.07, 32.73]
	Sensation Seeking	50.11	7.35	[48.13, 52.10]
	Sensory Sensitivity	34.89	6.77	[33.06, 36.72]
	Sensation Avoiding	32.33	7.14	[30.40, 34.26]

ITSP = Infant/Toddler Sensory Profile; AASP = Adolescent/Adult Sensory Profile.

Procedure

Ethics approval for the research was obtained from the participating organizations. Two main recruitment strategies were used. One involved direct approaches to mothers attending parent-information sessions at their local Maternal and Child Health Centre. The second strategy involved nurses identifying mothers and infants from their caseload whom they believed met the inclusion criteria and providing them with an information letter about the study. Those who were willing to be contacted by the researchers to discuss participation gave nurses written consent to have their contact details forwarded to the researchers.

A statewide public centre located in Melbourne and a private consultancy service for parents seeking assistance with infant settling assisted with recruitment for the present study. Nursing staff at these organizations were provided with a script for introducing the study to potential participants over the telephone, prior to treatment. Again, mothers who were willing to be phoned by a researcher to discuss participation in the study provided their contact details to nurses, who passed them to the research team.

Among the participants for whom complete data sets were obtained, 26% ($n = 14$) of the infants cried for more than $2\frac{1}{2}$ hr per day, on average, over the 4 days recorded in the diary. Attempts to recruit more participants with fussing, crying, and sleep problems through the private consultancy and the early parenting centre and by requesting that Maternal Child Health nurses identify potential participants known to have more unsettled infants were not successful. Data collection was carried out over 14 months between July 26, 2012 and September 17, 2013.

Consenting mothers who met the selection criteria, confirmed by telephone calls, were sent via mail an information letter, consent forms, and questionnaires. Consent forms and completed questionnaires were collected at a home visit, during which the Diary (Barr et al., 1988) was explained to mothers. The Diary was used to assess infant crying, feeding, and sleeping behaviors. Mothers were asked to complete the Diary within 1 week of the visit and return it to the researchers by mail.

RESULTS

Means, *SD*s, and lower and upper limits of the infant regulatory variables are presented in Table 1. Correlation analyses explored relationships between infant sensory processing and infant regulation. Moderated multiple regression analyses were performed to investigate whether maternal sensory processing moderated the relationship between infant sensory processing and infant regulation.

Mothers were excluded on the basis of severe postnatal depression (defined as having required inpatient treatment), other severe mental illness, or substance-use disorder.

Mean duration of sleep for this sample was 818 min, comparable with that of infant sleep reported in other studies (Sadeh, 2004; Spruyt et al., 2008).

Means, *SD*s, and 95% confidence intervals for the infant and maternal sensory processing variables are presented in Table 2.

All infant sample means were within the ITSP Scale's "typical performance" range, and all maternal sample means were within the AASP Scale's "similar to most people" range (Brown & Dunn, 2002). These data are consistent with studies that have reported the validation of the scale with samples of children without disabilities and have found that approximately two thirds of the items on the scale were uncommon behaviors for typical children (Dunn, 1994; Dunn & Westman, 1997). They also are reflective of the largely

TABLE 3. *Within-Task Correlations of the ITSP*

	Infant Low Registration	Infant Sensation Seeking	Infant Sensory Sensitivity	Infant Sensation Avoiding
Infant Low Registration		−0.12	−0.5	0.01
Infant Sensation Seeking	−0.12		−0.13	−0.12
Infant Sensory Sensitivity	−0.05	−0.13		0.36**
Infant Sensation Avoiding	0.01	−0.12	0.36**	

ITSP = Infant/Toddler Sensory Profile.
**$p < .01$.

TABLE 4. *Within-Task Correlations of the AASP*

	Adult Low Registration	Adult Sensation Seeking	Adult Sensory Sensitivity	Adult Sensation Avoiding
Adult Low Registration		−0.22	−0.41**	0.23
Adult Sensation Seeking	−0.22		−0.24	−0.51
Adult Sensory Sensitivity	0.41**	−0.24		0.63**
Adult Sensation Avoiding	0.23	−0.51**	0.63**	

AASP = Adolescent/Adult Sensory Profile. **$p < .01$.

TABLE 5. *Intercorrelations Between the ITSP and the AASP*

	Adult Low Registration	Adult Sensation Seeking	Adult Sensory Sensitivity	Adult Sensation Avoiding
Infant Low Registration	−0.16	−0.07	−0.11	−0.07
Infant Sensation Seeking	0.21	−0.54**	0.18	0.24
Infant Sensory Sensitivity	−0.13	0.08	−0.30*	0.21
Infant Sensation Avoiding	−0.10	0.12	−0.35**	−0.30*

ITSP = Infant/Toddler Sensory Profile; AASP = Adolescent/Adult Sensory Profile.
*$p < .01$.

nonclinical sample used in this study. Both infant and maternal data were normally distributed across all sensory processing quadrants.

Table 3 shows the within-task correlations of the ITSP. A significant positive correlation was found between Sensation Avoiding and Sensory Sensitivity.

Table 4 shows the within-task correlations of the AASP. A significant positive correlation was found between Adult Sensory Sensitivity and Low Registration, and between Adult Sensory Sensitivity Adult Sensation Avoiding. A significant negative relationship was found between Adult Sensation Seeking and Adult Sensation Avoiding.

Table 5 shows the correlations between the AASP quadrants and the ITSP quadrants. Significant negative correlations were observed between Adult Sensation Seeking and Infant Sensation Seeking, between Adult Sensory Sensitivity and Infant Sensory Sensitivity, between Adult Sensory Sensitivity and Infant Sensation Avoiding, and between Adult Sensation Avoiding and Infant Sensation Avoiding.

TABLE 6. *Pearson Correlations Between Infant Sensory Processing and Infant Regulation*

Sensory Processing	Sleep	Fussing	Crying	Fussing & Crying
Sensory Sensitivity	−.365**	.310*	.176	.323*
Sensation Avoiding	−.435**	.339*	.266*	.384*
Low Registration	.011	−.204	−.249	−.267*
Sensation Seeking	.023	.043	− .044	.017

*$p < .05$, two-tailed. **$p < .01$, two-tailed.

Data were examined for assumptions of normality using box plots, which revealed extreme values among 4 participants on the measures of infant Sensation Avoiding, infant Sensory Sensitivity, maternal Low Registration, and maternal Sensation Seeking. Each of these values was transformed to the next highest or lowest value. Following the transformations, histograms with normality curves, normal probability plots, skewness, and kurtosis were examined for each variable, all of which were found to meet assumptions of normality. Correlation analyses were conducted to test for associations between higher levels of Sensory Sensitivity and Sensation Avoiding and more fussing, more crying, and less sleep. The correlation matrix is presented in Table 6.

No significant differences were found between male and female infants in terms of regulatory factors or sensory processing. However, there was a negative, but nonsignificant, correlation between infant age and sleep, $r = -.253$, $p = .06$, consistent with reports of a normal developmental shift to less time spent asleep as infants mature (Galland, Taylor, Elder, & Herbison, 2012). Participants recruited through the private consultancy service, the parenting centres, and the local council services did not differ significantly on the major variables.

As predicted, a higher level of infant Sensory Sensitivity was moderately associated with less sleep, more time spent fussing, and combined fussing-crying. Contrary to expectation however, there was no significant association between infant Sensory Sensitivity and crying. As predicted, a higher level of Sensation Avoiding in infants was moderately associated with less sleep, more fussing, more crying, and more combined fussing-crying. A significant relationship also was revealed between high infant scores on Low Registration (indicating more awareness of stimuli) and combined fussing-crying. No other significant associations were found.

Finally, moderated multiple regression models were tested to investigate whether the association between infant Sensory Sensitivity and regulatory characteristics or infant Sensation Avoiding and regulatory characteristics was affected by the sensory processing characteristics of the mother. Figure 2 illustrates the model to be tested.

The PROCESS tool (Hayes, 2013) in SPSS Version 21.0 was used to test the moderation model, with a total of 32 combinations of the model tested. This revealed a significant negative association

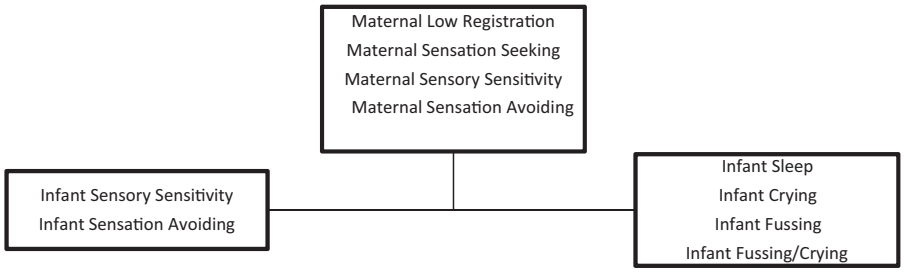

FIGURE 2. Moderation model to be tested.

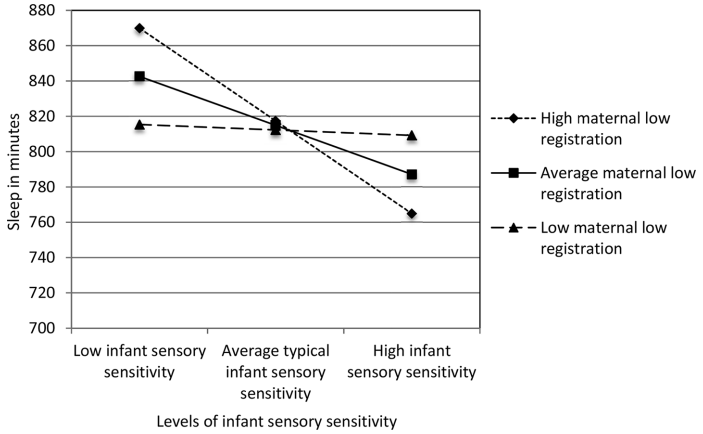

FIGURE 3. Conditional effect of Sensory Sensitivity on infant sleep, at low, average, and high levels of maternal Low Registration. Low, average typical, and high infant categories represent 1 *SD* below the sample mean, the mean, and 1 *SD* above the sample.

between infant Sensory Sensitivity and sleep, $\beta = 4.512$, $SE = 1.6$, $p < .01$. A negative interaction between infant Sensory Sensitivity and maternal Low Registration also was significant, suggesting that the effect of infant Sensory Sensitivity on sleep was strengthened by low levels of maternal Low Registration, $\beta = -.594$, $SE = .24$, $p < .05$. The interaction between these variables accounted for about 9% of the variance in sleep, $R^2 = .09$, $F(1, 51)$ 6.13, $p = .017$.

Figure 3 shows the simple slope for the interaction of the variables. The simple slopes tests at low (1 *SD* below the *M*), moderate (*M*), and high (1 *SD* above the *M*) levels of maternal Low Registration revealed that low and moderate levels of maternal Low Registration significantly increased the relationship between infant Sensory Sensitivity and reduced sleep, $\beta = 8.527$, $SE = 2.26$, $p < .001$, and $\beta = 4.512$, $SE = 1.6$, $p < .01$, at low and moderate levels, respectively), but there was no significant effect at high levels of maternal Low Registration. Thus, sensory sensitive infants slept even less if their mother was more attuned to sensory input in her environment. The effect of Sensory Sensitivity on reducing infant sleep was not significantly affected in cases where the mother had a high threshold to sensory input.

Data for visualizing the conditional effect of maternal Low Registration on infant sleep at the three mean centered levels of infant Sensory Sensitivity are presented in Table 7.

TABLE 7. *Infant Sleep Conditional Upon Maternal Low Registration, at Three Levels of the Sample Infant Sensory Sensitivity Score Range*

Infant Sensory Sensitivity	Maternal Low Registration	Infant Sleep
6.155	−6.76	764.95
.000	−6.76	817.42
−6.155	−6.76	869.92
6.155	0.0	787.08
.000	0.0	814.85
−6.155	0.0	842.62
6.155	6.76	809.20
.000	6.76	812.26
−6.155	6.76	815.32

Note. Infant sleep is represented in average minutes per 24-hr period.

A significant association also was revealed between infant Sensation Avoiding and crying, $\beta = -2.762$, $SE = 1.39$, $p < .05$. The interaction between infant Sensation Avoiding and maternal Low Registration also was significant, suggesting that maternal Low Registration significantly moderated the relationship between infant Sensation Avoiding and crying, $\beta = .552$, $SE = .24$, $p < .05$. The interaction between these variables accounted for about 23% of the variance in crying, $R^2 = .23$, $F(3, 51) = 6.79$, $p = .006$. Simple slopes for the association between crying and infant Sensation Avoiding were tested for low (1 *SD* below the sample *M*), moderate (*M*), and high (1 *SD* above the sample *M*) levels of maternal Low Registration. The simple slopes tests revealed significant associations between infant Sensation Avoiding and crying and at low, $\beta = -6.494$, $SE = 2.15$, $p < .01$, and moderate, $\beta = -2.76$, $SE = 1.39$, $p < .05$, levels of maternal Low Registration, but not at high levels (Figure 3). Hence, low-threshold, Sensation Avoiding infants cried even more if their mother had a high level of awareness of sensory stimuli in her environment. The amount of crying of infants with a Sensation Avoiding pattern was unaffected if their mother had a high neurological threshold and was less aware of sensory input. Table 8 presents the data illustrating the conditional effect of infant Sensation Avoiding on crying, at the three mean centered levels of the infant sample's Sensation Avoiding scores, and of the maternal Low Registration scores. Data for visualizing the conditional effect of maternal Low Registration on infant crying at the three mean centered levels of infant Sensation Avoiding are presented in Table 8, and Figure 4 plots the simple slopes for the interaction.

TABLE 8. *Infant Crying Conditional Upon Maternal Low Registration, at Three Levels of the Sample Infant Sensation Avoiding Score Range*

Infant Sensation Avoiding	Maternal Low Registration	Infant Crying
2.205	−6.76	45.50
.000	−6.76	31.18
−2.205	−6.76	16.87
2.205	0.0	40.73
.000	0.0	34.65
−2.205	0.0	28.56
−2.205	6.76	35.97
.000	6.76	38.11
2.205	6.76	40.25

Note. Infant crying is represented in average minutes per 24-hr period.

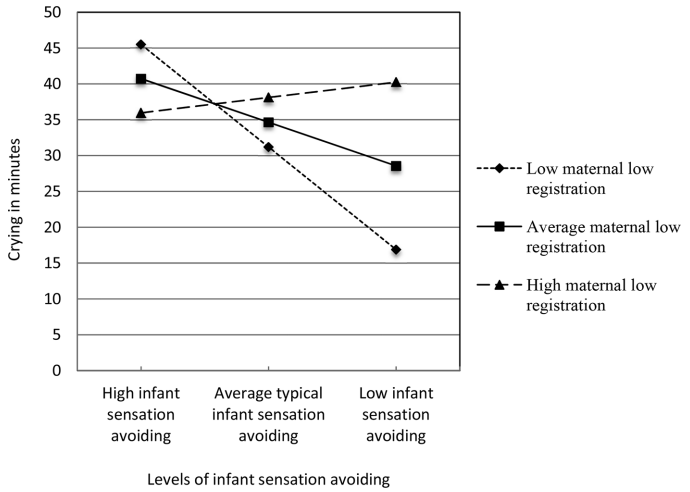

FIGURE 4. Conditional effect of Sensation Avoiding on infant sleep, at low, average, and high levels of maternal Low Registration. Low, average typical, and high infant categories represent 1 *SD* below the sample mean, the mean, and 1 *SD* above the sample.

Post hoc correlations revealed a significant association between mothers with higher scores on Low Registration and infant crying, $r(53) = .275$, $p < .05$. There were no other significant associations found between maternal sensory processing and infant regulatory variables.

Summary of Results

Consistent with the results of previous research, the present study found that infants with a low threshold for detecting sensory stimuli (higher levels of Sensory Sensitivity and Sensation Avoiding, measured by maternal report on the ITSP) had more regulatory difficulties than did infants with other sensory processing characteristics (DeSantis et al., 2004). In particular, infant Sensory Sensitivity was associated with more time spent fussing and less time sleeping, but was only associated with crying when combined with fussing. Infant Sensation Avoiding was associated with more time spent fussing, crying, and less time sleeping. Post hoc tests revealed that maternal Low Registration, indicative of a high neurological threshold and relatively passive behavioral response, was positively associated with infant crying. Examination of the moderating effects of maternal sensory processing revealed that low levels of maternal Low Registration (indicative of a more acute awareness of sensory stimuli) significantly moderated the effects of infant Sensory Sensitivity on sleep and of infant Sensation Avoiding on crying.

DISCUSSION

This investigation aimed to examine the relationship between sensory processing and regulatory capacities in infants between the ages of 4 and 7 months. The moderating effect of maternal sensory processing on the relationship between infant regulation and infant sensory processing also was investigated. The hypothesis that low sensory thresholds in infants would be associated with greater regulatory difficulties was supported. These findings are consistent with previous studies indicating that low sensory thresholds in infants are associated with more difficulty regulating affect and behavior (DeSantis et al., 2004). The results of this study also provide partial support for the proposal that the interaction between maternal and infant sensory processing influences infant regulation.

Sensory sensitivity, as measured by the ITSP, was associated with less sleep, more fussing, and more fussing and crying combined, but not with crying alone. Sensation avoiding, however, was associated with all three of the regulatory indicators examined in this study—less sleep, more fussing, and more crying—and with the combined fussing and crying variable.

According to Dunn's (1997) model, sensory sensitivity is accompanied by behavioral responses in accordance with the high registration of stimuli, as opposed to responses attempting to counteract the registration of stimulation. Behavioral responses in accordance with sensory thresholds tend to be more passive than active in manner. It is proposed that fussing may be understood as a more passive means of signaling distress or discomfort than is crying, and therefore is a more prevalent signal in sensory sensitive infants. Avoidance of sensations, while also indicative of a low neurological threshold, is at the opposite end of the behavioral response continuum, according to Dunn's model. Infants who avoid sensations attempt to counteract their low threshold for sensory input with more active behaviors. Crying may be understood as a more active and energetic means of signaling a need for support to a caregiver, accounting for its association with sensation avoiding in this sample of infants, along with fussing and reduced sleep. Further investigation is warranted to validate these proposed functions of crying and fussing behaviors within Dunn's model.

In terms of the more general research question of whether, and in what manner, maternal sensory processing would moderate the relationship between infant sensory processing and infant regulation, it was found that low and moderate scores on Low Registration in mothers (indicative of acute to moderate awareness of

stimuli) significantly contributed to reduced sleep in more sensory sensitive infants. In addition, more acute awareness of stimuli in mothers significantly contributed to crying in infants with higher levels of sensation avoiding.

Extensive use of the Sensory Profiles in nonclinical samples has not been reported to date. Therefore, limited data are available about the implications of sensory functioning closer to the borders between the quadrants. There is likely to be some overlap between characteristics and behaviors at low levels of one sensory processing quadrant and high levels of another; however, the nature of the characteristics and behaviors closer to the boundaries of the quadrants has not been clearly delineated or validated. Regarding use of the AASP in this study, it therefore is possible to draw only tentative conclusions about the moderating effect of low maternal Low Registration on infant regulation.

At lower levels of Low Registration, mothers are likely to be acutely aware of all stimuli in their environment and may have difficulty screening out or modulating sensory input. The Sensory Profile Supplement to the ITSP (Dunn, 2006) describes low scores in the Low Registration quadrant as indicative that children will be likely to notice things and be highly attentive to activity in their environment, without necessarily being bothered by their awareness. Extrapolating to the experience of a first-time mother managing the crying and sleep of an infant with a low neurological threshold (sensation avoiding or sensory sensitive), it is possible that if the mother is hyperaware and hypervigilant to signs of unsettled behavior, she may act too early and too often to intervene in her infant's regulation. Infants with a more sensory sensitive pattern are more likely to notice detail, to be aware of changes to setting and mood that others may not notice, and be more distractible (Dunn, 2006). They may become overwhelmed by too many changes to stimuli and need predictability and slow sensory transitions, particularly when attempting to settle to sleep. By changing the environment, and adding stimulation, a mother inadvertently might further unsettle her infant. A mother who is acutely aware of stimuli and who tends to act to control the environment to meet the needs of her own sensory threshold may misread subtle cues in her infant, thereby attempting settling interventions which are intrusive and interfere with the infant's attempts to self regulate.

The mechanism by which a mother's acute awareness of stimuli in her environment moderates crying in infants with a sensation-avoiding pattern also is unknown. Dunn (2006) suggested that children with this profile notice more, are bothered by things more than are others, are likely to want to withdraw from overwhelming stimuli, and are best supported when there is less sensory input available in the environment. If their crying signals are met with an overly active, attentive response from their mother, who is responding according to her own acute sensory awareness, it may serve to exacerbate crying.

Bivariate correlations between maternal sensory processing and infant regulation variables revealed a significant association between mothers with higher scores on Low Registration (indicative of low sensory awareness and a slow response to stimulation) and infant crying. It may be that infants have greater difficulty regulating their emotion and self-soothing when their mothers are more disengaged from their signals and are slow to respond to their needs.

These findings support the proposal that where regulation of fussing, crying, and sleep pose a problem for mothers and infants beyond 3 months of age, sensory processing assessment may provide useful clinical information for professionals in diagnosis and treatment. Helping mothers understand their infant's sensory processing and the interaction with their own sensory processing may provide a nonjudgmental and practical focus for therapeutic intervention along the lines of Dunn's (2006) recommendations. In the short-term, improvements in infant regulation are likely to benefit mothers and families in terms of reducing fatigue, anxiety, and stress and the contribution of these factors to maternal depression and the potential for infant abuse. There may be positive implications for the development of infant–parent attachment as well as for reducing the risk of longer term behavior problems developing in childhood.

Some limitations need to be considered when interpreting the results of this study. First, the small sample limits the applicability of these findings to a narrow population of well-regulated infants, infants and mothers with relatively typical sensory processing, and mothers with a high level of education. Although large effects were detectable with the sample of 55 participants, additional, small effects may have been detected with a larger sample. We also acknowledge that the large number of tests conducted with the data carries a risk of Type I error. Therefore, replication with a larger sample in future research is advisable.

Second, the low number of infants approaching any level of regulatory disorder limits the degree to which the findings of this research can be generalized to nonclinical, well-regulated infant populations. It therefore was not possible to compare groups, and the fussing, crying, and sleep data were used as continuous measures.

Third, the reliability coefficients reported for the ITSP quadrants in this study and in others are lower than desirable. The imprecision of the infant and adult sensory processing measures along with the validity and meaning of scores toward the boundaries of the quadrants make only general speculation possible about the meaning of the moderating effects in this sample of mothers on their infants' regulatory capacities. The sensory processing measures relied on parent-report for the infant and self-report for the mothers without standardized validation. It is possible that a mother's capacity to accurately detect and report on her infant's sensory awareness and her interpretation of the infant's responses are limited by her own sensory awareness.

Mothers with infants experiencing regulatory problems are likely to have declined the invitation to participate in the research for a variety of reasons including, but not limited to, care burden and fatigue. Conducting research with this population in a hospital setting or residential parenting centre would afford more time flexibility and opportunities to develop a trusting relationship with mothers, which may facilitate their participation in similar research in the future.

Clinical Implications

Consistent with the findings of previous research, data obtained in the present study indicate associations between low neurological thresholds for sensory processing and increased crying, fussing, and reduced sleep in a sample of infants from 4 to 7 months of age. The findings that infants with low thresholds who are more passive in behavioral response (sensory sensitive) fussed, but did not cry significantly more than did those with high thresholds, and that sensation-avoiding infants also cried significantly more than did high-threshold infants, may be a useful contribution to understanding the variation in communication signals of infants with high levels of sensory awareness. Infants at all points along the behavioral response continuum of the low-threshold profile are likely to need additional support from caregivers. Sensory sensitive infants, however, may communicate their needs less energetically by fussing while sensation-avoiding infants may be relatively more likely to cry.

The current study's exploration of the moderating effects of maternal sensory processing on infant sensory processing and regulatory behaviors are an important first step in understanding the relationship between infant and parent sensory processing. Replication of the results with a larger and more diverse sample of parents and infants also is recommended. It is hoped that such developments will improve the information available to parents about the interactions between them and their infants and support them in optimal parenting practices.

The results of the present study indicate that assessment of sensory processing may be valuable in assisting parents to support their infant's developing regulatory capacities. It also provides some evidence that maternal sensory processing, particularly where maternal profiles are less typical, may have a moderating influence on the relationship between infant sensory processing and regulation. Future research exploring these relationships and investigating the sensory awareness and behavioral differences in mothers related to infant care may benefit from the development of more robust measures of infant and adult sensory processing.

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