Staying in Touch:

Mothers' and Infants' Dyadic Touching Behaviours Across Time, Context, and Risk Status

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A Thesis

In the Department of

Psychology

Presented in Partial Fulfillment of the Requirements

For the Degree of

Doctor of Philosophy (Psychology) at

Concordia University

Montreal, Quebec, Canada

March 2022

CONCORDIA UNIVERSITY

School of Graduate Studies

This is to certify that the thesis prepared

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Entitled: **Staying in Touch: Mothers' and Infants' Dyadic Touching Behaviours Across Time, Context, and Risk Status**

and submitted in partial fulfillments of the requirements for the degree of

Doctor of Philosophy, Psychology

complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Date of defence: May 6, 2022

ABSTRACT

Staying in Touch: Mothers' and Infants' Dyadic Touching Behaviours Across Time, Context, and Risk Status

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Concordia University, 2022

Touch is the basis of infants' social, emotional, and cognitive development. Yet, it remains largely understudied in developmental research. A series of three studies were designed to expand our limited knowledge of parents' and infants' touching behaviours, including the synchrony of maternal-infant touch, across various types of parent-child interactions over time.

Study 1 utilized an extensive longitudinal design whereby healthy mother-infant dyads (N=12) were observed at 1-, 3-, 5-, 7-, and 9-months postpartum and within two normative interaction contexts (face-to-face; floor play). Study 2 implemented a longitudinal research design whereby typically developing newborns, mothers, and fathers (N=22) were observed immediately after birth and following the physiological stress of labor/delivery, and again 3-months later, following the social stress of maternal emotional unavailability via the Still-Face procedure (SF; Tronick et al., 1978). Study 3 used a cross-sectional research design examining mother-infant dyads (N=41) with high vs. low risk of maternal depressive symptomatology during instances of infant crying within the context of the SF and Separation (SP; Field et al., 1986) procedures at 4-months postpartum.

Overall, results revealed that touch is a pervasive and extensive communicative modality for both infants and parents, including those at-risk, within normative and perturbed contexts, starting from birth and across the first 9-months of life. Study 1 demonstrated that during typical/playful mother-infant interactions from 1- to 9-months postpartum, dyads initially

displayed behavioural matching and later transitioned toward synchronous patterns entailing the parallel use of complementary types of touch. Study 2 revealed that mothers and infants displayed an inverse pattern of tactile synchrony (coordinated, converse changes in touch) from the immediate postpartum period to the reunion period of the SF procedure 3-months later. In Study 3, mothers and infants displayed a positive pattern of tactile synchrony (coordinated, analogous changes in touch) within the context of infant crying at 4-months postpartum. However, dyads in the high depression group displayed significantly less affectionate touch. Among other findings, results from all three studies underscored the soothing and regulatory functions of touch. Findings meaningfully contribute to our knowledge of early parent-infant dynamics and support a direction toward comprehensive examinations of touch across infancy.

Acknowledgments

My deepest gratitude is firstly extended to my supervisor, Dr. Dale M. Stack. You have truly been an exceptional mentor. I sincerely appreciate the continuous and unwavering support you have provided me over the years. Your uplifting energy, excitement, and encouragement have played a key role in making my graduate experience both positive and rewarding. Thank you for sharing your passion of touch and development with me. The knowledge and skills you have relayed to me – on a research, clinical, and personal level – are invaluable.

I would also importantly like to thank my co-supervisor and thesis committee member, Dr. Lisa A. Serbin, for her instrumental support and input. Additionally, I would like to thank Dr. Nina Howe for serving on my thesis committee and providing me with helpful revisions and comments. My genuine appreciation likewise extends to our collaborators, Drs. Rosario Montirosso, Alan Fogel, and Tiffany Field, each of whom were essential and greatly contributed to the development of this research. Furthermore, I would like to express my profound appreciation toward the mothers, fathers, and infants for their time and willingness to participate. You have collectively afforded us the opportunity to advance our understanding about the importance of touch to the parent-infant relationship and infant well-being.

To the members of the Stack Lab, both past and present – thank you for providing me with an enjoyable work environment. The support you have each provided me has been a meaningful part of this journey. I cherish the experiences we have shared and the friendships we have formed.

To my parents and family – thank you for endlessly supporting my studies and career aspirations. I am so grateful for your unconditional love and validation, and for always reminding me of how proud you are of my accomplishments. Chris, thank you for keeping me

focused and being my biggest motivator. I am so incredibly fortunate to have you in my life; it has been such a special experience to have completed our dissertations together, all while building our future together.

Contributions of Authors

The current dissertation consists of three manuscripts:

Study 1 (see Chapter 2)

Mercuri, M., Stack, D.M., De France, K., Jean, A.D.L., & Fogel, A. (Under review). An intensive longitudinal investigation of maternal and infant touching patterns across context and throughout the first 9-months of life. *Infant Mental Health.*

Study 2 (see Chapter 4)

Mercuri M., Stack D.M., Trojan S., Giusti L., Morandi F., Mantis, I., & Montirosso, R. (Under review). From the First Touch: Newborns' and parents' touching behaviours during triadic and dyadic interactions immediately after birth and at 3-months postpartum. *Infancy.*

Study 3 (see Chapter 6)

Mercuri, M., Stack, D.M., Mantis, I., Moszkowski, R., & Field, T.M. (Under review). Maternal and infant touching behaviours during perturbed interactions: Associations with maternal depressive symptomatology and infant crying. *Infant Behavior & Development.*

My supervisor, Dr. Dale M. Stack, and I are responsible for the conceptualization of the research presented in all three studies of this dissertation. The data used in Study 1 was collected by Dr. Alan Fogel's research team at the University of Utah. The data used in Study 2 was collected by Dr. Montirosso's team at the 0-3 Center for the at-Risk Infant, Scientific Institute IRCCS, as well as the staff from the Obstetrics and Gynecology Unit of the Sacra Famiglia Hospital of Erba (Como), Italy. The data used in Study 3 was collected by Dr. Tiffany Field's research staff at the Touch Research Institute, University of Miami School of Medicine. In addition to collecting the original data, all three collaborators (i.e., Drs. Fogel, Montirosso, and Field) developed the designs and methods for the original respective studies from which the current dissertation, and its original foci and themes, was developed and derived.

Behavioural observational coding for all three studies was completed by me in Dr. Stack's Infant and Child Studies Laboratory, Concordia University. A portion of the behavioural observational coding was also completed by Drs. Amélie Jean (Study 1), Irene Mantis (Study 3), and Robin Moszkowski (Study 3), former graduate students in Dr. Stack's laboratory. Following the reliability and observational coding, I completed data entry and cleaning procedures using statistical software. With guidance and input from Dr. Stack, I formulated the research questions, hypotheses, and analyses plans. I also completed the statistical analyses, interpreted the results, and wrote all components of this dissertation. Dr. Stack provided feedback at every step, including revisions and edits to the text.

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Chapter 1: General Introduction

Our sense of touch underlies every one of our life experiences. Touch is embedded in moments that are mundane (e.g., sitting still, scratching an itch), yet is also pervasive during those that are meaningful (e.g., hugging a loved one in celebration; Klatzky & Lederman, 2013). In fact, touch affords us with our very *first* set of sensorial experiences given that the somatosensory system is the earliest to emerge, beginning at just 6 weeks gestation (Cascio et al., 2019; Montagu, 1971, 1986; Stack, 2010). Tactile stimulation is ubiquitous within the womb, as it is provided to the fetus by being suspended in amniotic fluid and through the uterine wall during maternal movement (Field, 2010; Mantel et al., 2021). However, the fetus is not merely a recipient of touch but is also an active user of the tactile modality. That is, the fetus explores its surrounding environment and begins to discover itself as a separate entity using touch (Crucianelli & Filipetti, 2020; Montirosso & McGlone, 2020). Somatosensory information is concurrently obtained and transmitted to the skin, the largest sensory organ which covers the entire body's surface (Serino & Haggard, 2010). Touch is also the most primary means of contact infants have with the outside world, as they continue to receive and respond to tactile stimulation during birth, in the moments that immediately follow labour and delivery, and onward across the lifespan (Gallace & Spence, 2016; Lowe et al., 2016; Mercuri et al., 2019; Wiberg, 1990; Widström et al., 2020). During the initial neonatal period and throughout infancy, parents utilize touch to carry out necessary caregiving behaviours such as holding, feeding, bathing, grooming, and dressing (O'Brien & Lynch, 2011; Wiberg, 1990). Additionally, parents use touch to comfort, soothe, stimulate, and play with their infants, as well as to express love and affection (Jean & Stack, 2009; Jean et al., 2009). By extension, infants learn how to use touch to effectively regulate and express their emotions, engage socially with others, and explore themselves and their environment (Stack, 2010). Therefore, touch is the basis of infants'

embodied interactions with their parents, the parent-infant relationship, and more broadly, infants' social, emotional, and cognitive development (Nguyen et al., 2021; Phillips, 2013).

The omnipresence of touch throughout the earliest, and perhaps the most pivotal, stage of development (i.e., the neonatal period) underscores the extensive implications tactile contact has for infants' health and well-being. The extensive benefits of touch are evidenced by research on skin-to-skin contact (Kostandy & Ludington- Hoe, 2019), also known as Kangaroo care (Rey & Martinez, 1983). This practice entails placing the infant's naked body onto their caregiver's bare chest immediately after birth, thereby providing the infant with a form of physical contact that is close, warm, and continuous and which parallels the prenatal environment (Beijers et al., 2016; Chen et al., 2017; Cleveland et al., 2017; Owusu-Ansah et al., 2019). Early skin-to-skin contact has been found to have regulatory effects on the most essential components of neonatal survival, including respiration, heart rate, temperature, cortisol secretion, and sleep (Acosta, 2016; Bystrova et al., 2003; Erlandsson et al, 2007; Ferber & Makhoul, 2004; Walters et al., 2007; Winberg, 2005). Additionally, skin-to-skin contact has been found to facilitate breastfeeding, improve weight gain, and reduce crying (Field et al., 2011; Marín Gabriel et al., 2010; Neu et al., 2008). Massage, a practice involving the systematic application of touch, and which is used as a traditional form of medicine cross-culturally (e.g., East Indian body massage as discussed by Leboyer, 1976), produces comparable advantages as it helps stabilize infants' physiological, affective, and behavioural states (Bayomi et al., 2015; Field, 2019; Kulkarni et al., 2010). These benefits extend to infants placed in Neonatal Intensive Care Units (NICUs) due to premature birth, low birthweight, and other conditions. Both skin-to-skin contact and massage are recognized as effective interventions for this group of infants, who are more vulnerable given potential delays in their physical development and exposure to pronounced forms of stress and pain resulting from medical procedures as well as parental separation (D'Agata et al., 2017;

Field, 2016; Montirosso et al., 2016; Stack & Jean, 2011). Among both at-risk and typically developing infants, early physical contact is linked to positive long-term outcomes such as better self-regulatory abilities, less emotional negativity, and less irritability in infants one year after birth (Bystrova et al., 2009).

The numerous benefits of early tactile contact have also been well documented within the animal literature. Rodent studies have revealed that maternal licking and grooming, which are the typical touch behaviours of rat mothers, shape the rat pup's stress management systems (e.g., neuronal systems that regulate endocrine and behavioral responses to stress) and permanently change how the rat responds to stressful events (Champagne, 2008; Champagne & Meaney, 2007; Meaney, 2001; Menard et al., 2004). The biochemical processes involved in the growth and development of rat pups are negatively altered when they are separated from their mothers and no longer receive maternal licking and grooming (Schanberg & Field, 1988). Interestingly, the negative effects of maternal deprivation are reversed by stroking rat pups with a soft brush (Kuhn et al., 1990; Suschecki et al., 1993; Schanberg, 1995). Classic studies by Harlow and colleagues (Harlow, 1959; Harlow & Harlow, 1962a; 1962b; Harlow & Zimmermann, 1958) on infant rhesus monkeys also revealed the significance of early tactile contact that is soft in nature. In these experiments, infant monkeys were provided with two surrogate mothers: a "wire mother" which provided the infant with milk and embodied nourishment, and a "cloth mother" which provided a sense of warmth, comfort, and safety. Although the infants went to the wire mother for milk, they consistently returned and clung to the cloth mother. This pattern was even more pronounced when the infants were exposed to an unfamiliar condition (e.g., novel mechanical toy) and were maintained even when dangerous conditions were paired with the cloth mother (e.g., violent shake, air pressure). Such research underscored gentle touch as being

the most essential component to the attachment that forms between mother and infant (Botero et al., 2020; Harlow, 1971).

More recently, research on both humans and animals has explored the neural mechanisms underlying the innate preference of nurturing forms of tactile contact. A specific group of nerve receptors known as the C-Tactile (CT) afferents have been identified solely in the hairy skin of mammals including rodents, as well as human and non-human primates (Pitcher et al., 2016). CT afferents are activated in the part of the brain that processes emotion and well-being in response to slow (velocity in the range of 1-10 cm/s), caress-like types of touch such as stroking, which is delivered at normal skin temperature (Ackerley et al., 2014; Botero, 2018; Crucianelli & Filippetti, 2020; McGlone et al., 2017). Therefore, this set of nerve fibers are responsible for the hedonic sensations derived from tactile contact and have a central role in experiencing emotion during interpersonal touch (Botero et al., 2020; Löken et al., 2009; McGlone et al., 2014; McGlone et al., 2017). Previous studies suggest that the neural network responsible for detecting pleasant sensations from touch is already functional at birth and continues to mature across the first year of life (Jönsson et al., 2017; Miguel et al., 2019; Tuulari et al., 2019).

It is important to note, however, that a general preference for CT-optimal (i.e., affective) touch has been found across different age groups across the lifespan, and not just among newborns and infants (Brazelton, 1977; Cruciani et al., 2021). As such, CT afferents account for the mutually rewarding nature of touch during caregiver-infant interactions (Löken et al., 2009; Olausson et al., 2016). Indeed, the inherent reciprocity of touch is noted as its most unique feature in comparison to all other senses, as one cannot touch someone else without simultaneously experiencing touch themselves (Ciaunica & Fotopoulou, 2017; Crucianelli & Filippetti, 2020; Florita, 2021; Morrison et al., 2010). Taken together, affective touch via the CT

afferents promotes affiliative contact and attachment (Mantel et al., 2021) and supports humans' biological predisposition to be social (Castiello et al., 2010; Owusu-Ansah et al., 2019).

Gaps in the Extant Touch Literature

While the recent discovery of CT-afferents has added to our understanding about *why* social touch is pleasant and rewarding for infants and their parents, our knowledge about *how* they each use touch during their social interactions is still incomplete. Despite the pervasiveness of touch during infancy and the significant implications of touch regarding infants' psychological and physiological well-being, touch is the most neglected communicative modality within developmental research (Botero et al., 2020; Brzozowska et al. 2021; Stack, 2010). Of the studies which have included touch in their investigations of parent-infant interactions, many have failed to account for its multidimensional, dynamic, and evolving nature. According to a recent review by Botero and colleagues (2020), touch is consistently mentioned throughout the extant literature but is rarely examined in an in-depth or systematic manner. Instead, the tactile modality is commonly regarded as a general construct with one-dimensional properties. That is, touch is typically included as a global behaviour in observational coding systems applied to parent-infant interactions, such as those aimed at understanding parent-infant attachment and maternal sensitivity (Botero et al., 2020). Such examinations are insufficient given touch goes well beyond static physical contact and comprises several other types of tactile behaviours (e.g., stroking, rubbing, tapping, patting) which are employed at varying quantities (e.g., frequencies, durations), and which range in speed, force, temperature, and location (Hertenstein, 2002; Hertenstein et al., 2006). Furthermore, touch has several integral functions (e.g., communicative, utilitarian, regulatory, playful, etc.) and is intrinsically tied to the specific context and developmental period it occurs in (Field, 2019; Jean & Stack, 2009; Mercuri et al., 2019; Moszkowski et al., 2009; Stack, 2010). The incredible amount of rich information conveyed through touch is best captured

when brought to the foreground of research designs and measured as a multidimensional construct.

In addition, previous investigations of touch, including those which have been more detailed and systematic (e.g., Crucianelli et al., 2019; Ferber et al., 2008; Jean et al., 2009; Jean et al., 2014; Mantis et al., 2019; Mercuri et al., 2019; Moszkowski et al., 2009; Moszkowski & Stack, 2007; Stack & Muir, 1990), have primarily entailed unidirectional examinations of touch, focusing on *either* parental *or* infant touch. Because parents have a larger and more sophisticated behavioural repertoire, and mothers are often considered primary caregivers, much of the extant literature pertaining to the tactile modality within the context of parent-infant interactions has centered on maternal touch alone (Mantis et al., 2014). Within these same studies, *infants'* displays of affect, gaze, or vocalizations have typically been measured rather than their respective displays of touch (e.g., Esposito et al., 2017; Feldman et al., 2010). Our existing knowledge about the development of infant touch primarily stems from research on proprioception and which describes infants' spontaneous bodily movements while alone in the supine position (e.g., DiMercurio et al., 2018; Thomas et al., 2015). Consequently, little is known about the scope and pervasiveness of infant touching behaviours during reciprocal exchanges with their caregivers and how infants' use of touch is interconnected with that of their parents. It is striking that infant touch has been overlooked within this line of research given that touch is the earliest mode of communication to emerge and is a sense that is inherently social (Hertenstein, 2002; Field, 2019; Nguyen et al., 2021).

Mantis and colleagues (Mantis & Stack, 2018; Mantis et al., 2014) were amongst the first to examine the communicative properties of touch through a bidirectional, rather than unidirectional, process. Specifically, they investigated mutual touch among mothers and their full-term and very low-birthweight (VLBW) preterm infants across a series of face-to-face

interactions at 5 ½-months postpartum. These studies revealed that overall, mother-infant dyads use touch simultaneously for over one third of their face-to-face interactions and appear to jointly use touch as a means of regulating infant affect following a brief period of maternal emotional unavailability. Moreover, VLBW/preterm infant-mother dyads were found to engage in significantly more unbalanced (i.e., unmatched) mutual touch as compared to full-term infant-mother dyads, demonstrating variations in tactile communication based on risk status (Mantis & Stack, 2018). Such findings illustrated that *both* mothers and infants participate in shaping and co-regulating their interactions through touch and support the continued employment of bidirectional investigations of touch among typically developing and at-risk groups (Mantis et al., 2014). While this research represented an important step forward within the literature, additional investigations which assess the concurrent and longitudinal changes in the specific types and amount of maternal and infant touch are essential to understanding the dynamic patterns that unfold during early social exchanges across infancy.

In particular, synchrony represents a noteworthy dynamic pattern characteristic of mother-infant interactions (Harder et al., 2015; Leclère et al., 2014; Feldman, 2017). It is an essential component of early social exchanges which allows interactions to be mutually rewarding, precedes the emergence of infants' self-regulatory abilities, and promotes the development of a healthy mother-infant relationship and other future relationships (Harrist & Waugh, 2002; Reyna & Picklet, 2009). Synchronous mother-infant interactions are understood as an observable pattern of harmonious and reciprocal social exchange (Reyna & Picklet, 2009). Concretely, synchrony is defined as the degree of temporal coordination between maternal and infant behaviours (Busuito et al., 2019; Hsu & Fogel, 2001). Investigations of behavioural synchrony to date have focused predominantly on the visual (facial expressions, gaze) and vocal (vocalizations) modalities (Harder et al., 2015; Della Longa et al., 2020). In line with the touch

literature, the few studies which have examined mother-infant synchrony while accounting for the tactile modality have been quite limited, as they have only considered the individual trajectories of either maternal *or* infant touch alone (e.g., Babik et al., 2014; Chinn et al., 2019).

For example, despite claims that they were measuring "touch synchrony," Feldman and colleagues (2010) examined only maternal and not infant touch during instances of shared gaze. Hence, researchers have yet to assess and describe the synchrony of maternal *and infant* touch, especially at a micro-behavioural level whereby the individual types and amount of their respective tactile behaviours are captured. Interestingly, touch and synchrony, when measured as separate constructs, have each been associated with more positive child outcomes including the formation of a secure attachment (Isabella & Belsky, 1991; Feldman, 2017) and improved psychological and emotional well-being (Ambrose & Menna, 2013). These parallel benefits suggest that the synchrony of mother-infant touch itself (i.e., tactile synchrony) may be an important mechanism through which infants develop their social, emotional, and communicative skills. Research examining tactile synchrony within and across mother-infant interactions over time is thus warranted, as it would elucidate our understanding of how healthy infant development, including the formation of a positive mother-infant relationship, is fostered through touch.

Guiding Theories

Dynamic and transactional models of development are foundational to our emerging understanding of touch as a reciprocal form of communication with marked importance throughout infancy. According to the dynamic systems perspective, parents and their infants form a mutually regulated bidirectional system and are each sensitive and responsive to changes in their partner (Beebe et al., 2016; Field, 2014; Fogel, 1993; Fogel, 2009). The Mutual Regulation Model (MRM) likewise underscores the dynamic and bidirectional processes intrinsic

to mother-infant interactions, which comprise a collective exchange of communicative signals that guide both mothers and infants toward a synchronous behavioural dialogue (DiCorcia & Tronick, 2011; Tronick, 1989; Tronick & Weinberg, 1997; Weinberg et al., 2006). Since disruptions are expected to occur during their interactions, mothers and infants must appropriately interpret and respond to one another's communicative cues to successfully repair moments of disruption and return to synchrony (Leclère et al., 2014; Weinberg et al., 2006). The reparative process is viewed as an essential component of cascading infants' social, behavioural, and emotional development (DiCorcia & Tronick, 2011). These views are consistent with bidirectional and transactional models of development which posit that the behavioural changes displayed by a parent are likely to influence their child's behaviour, and vice versa (Pesonen et al., 2008; Sameroff, 2010). Taken together, mothers and their infants are an integrated, coupled system (Beebe et al., 2016; Fogel, 2009).

Therefore, investigations of touch should capture both mothers and their infants as active and competent social partners and be reflective of the bidirectional nature of their interactions and, more broadly, their relationship (Field, 2014; Pettit & Arsiwalla, 2008). The extensive short- and long-term benefits of touch to infant well-being, and the pervasiveness of touch during parent-infant interactions, warrant more detailed examinations designed to capture the reciprocal dynamics of parent and infant touch within and across their social exchanges. In the absence of studies informed by dynamic and transactional models, our understanding of how parents and infants collaboratively use touch to contribute to their interactions and by extension, infants' healthy development, remains incomplete. The general aims of the present dissertation are thus grounded in the aforementioned guiding theories and principles.

Dissertation Objectives

Building on the existing empirical and theoretical knowledge of touch and parent-infant interactions, as well as the corresponding gaps in the extant literature discussed above, the overall aim of the present dissertation was to obtain a more complete understanding of how mothers and infants jointly use touch throughout their interactions. The primary objectives were to examine the ways in which mothers and infants use touch as a shared form of early communication, and how the dynamics (i.e., tactile synchrony) of mother-infant touch unfold according to contextual factors and over time, starting immediately after birth and throughout the first 9-months of life.

These objectives were addressed by three studies (outlined below), each of which assessed the quantity (duration) and quality (type) of the full range of specific and more general touching behaviours displayed simultaneously and synchronously by mothers and their infants. Touching behaviours were explored within and across various types of interactive contexts based on existing evidence that different observational settings have diverse effects on interactive behaviour (Dittrich et al., 2017; Feldman et al., 1997; Jean & Stack, 2009) and that touch is meaningfully tied to contextual factors (Hertenstein, 2002; Stack & LePage, 1996) including the positioning of the dyad and elements of their surrounding environment such as the presence of toys (Jean et al., 2009; Mercuri et al., 2019). Both typically developing and at-risk dyads were examined to further advance our knowledge of mother-infant touch and its role in healthy infant development; namely, infants and mothers with high levels of depressive symptomatology were assessed in light of research illustrating their potential for impaired regulatory abilities and atypical social exchanges (Ntow et al., 2021; Pearson et al., 2012).

The Present Studies

Study 1 was devised to extensively explore the progression of both maternal and infant touch patterns, including the synchrony of mother-infant touch. Healthy mother-infant dyads

were examined systematically and longitudinally at 1-, 3-, 5-, 7-, and 9-months postpartum and within two interactive contexts, each representative of everyday mother-infant interactions as they involved typical positioning and age appropriate-toys. The initial 9-months of life was selected as a period of observation given that it is regarded as a sensitive period of development (Feldman, 2015) and both touch and synchrony during this span of time have long-term implications for infants' social and emotional well-being (Granat et al., 2017). Thus, the primary objective of Study 1 was to obtain a more complete understanding of how maternal and infant touch typically develops, and how both mothers and infants use touch to achieve synchrony during their early naturalistic interactions across time and context.

Study 2 was formulated to further explore the development of touch and tactile synchrony in healthy families. This study expanded on Study 1 by assessing mothers', fathers', and their infants' very first, naturalistic displays of touch immediately after birth and in the unique setting of the hospital delivery room. The immediate postpartum period is a meaningful and distinct interactive context that has been vastly overlooked despite research indicating that touch occurring at this time encourages parent-infant bonding and attachment (Anisfeld & Lipper, 1983; Greenberg & Morris, 1974; Moore et al., 2007) and is associated with subsequent caregiving practices (Bell et al., 2018). As such, the touching behaviours of these same mothers and infants were examined 3-months later using the Still-Face procedure (SF; Tronick et al., 1978), a structured set of face-to-face interaction periods consisting of two normative interactions separated by a brief period of maternal emotional unavailability. Our previous investigation of this sample unveiled the parallel nature of the post-birth and post-SF contexts; respectively, these contexts exposed infants to the physiological stress of being born and the social stress of violated social norms and expectancies (i.e., by maintaining a still face, mothers interacted with their infants differently than they typically would; Mercuri et al., 2019). Study 2

expanded on our prior research by examining the predictive quality of newborn touch and the development of mother-infant synchrony across these perturbed contexts over time. An additional, yet important, objective of Study 2 was to explore the interplay between maternal, paternal, and newborn touching behaviours and other more global behaviours characteristic of the immediate postpartum period. Specifically, parent and newborn touching behaviours were examined in relation to newborn crying/fussing, behavioural displays of maternal pain, and breastfeeding to deepen our understanding of touch and its vital role at birth and onward.

Study 3 was designed to expand our understanding about the synchrony of maternal and infant touch within the context of perturbed mother-infant interactions, while also considering the influence of maternal depressive symptomatology. This is an important focus given that postpartum depression is a common form of psychopathology that places mother-infant dyads at-risk in terms of their ability to repair interactive disruptions and mutually regulate (Granat et al., 2017; Laurent & Ablow, 2012). Mothers and their 4-month-old infants participated in the SF procedure (described above and used in Study 2) as well as the Separation procedure (SP; Field et al., 1986); the latter consisted of a series of dyadic face-to-face interactions where mothers interacted naturally for two periods, separated by a brief perturbation where mothers physically leave the room to go behind a nearby curtain for a very brief period of time. The infant crying episodes that occurred following these periods of maternal emotional (SF) and physical (SP) unavailability were themselves regarded as a perturbation context and representative of typical displays of mild infant stress (Augustine & Leerkes, 2019; Horowitz et al., 2019). Study 3 thus explored synchronous maternal and infant touching patterns specifically during instances of infant crying to enhance our knowledge of how and to what extent depressed and non-depressed dyads use touch to repair disruptions in their early face-to-face interactions. By extension, Study

3 was expected to elucidate our understanding of whether and how risk associated with maternal depression may be transferred to infants' psychosocial and emotional development via touch.

This dissertation was intended to provide unique directions for the study of touch as a primary means of communication across naturalistic, experimental, and perturbed interactions beginning from the first hour after birth and across the initial 9-months of life. Individually and collectively, the present studies were expected to fill important gaps by exploring multiple parameters of touch across varied interactive settings throughout a critical period of development, that of the first 9-months of life, and by examining touch from a bidirectional perspective, allowing for the degree of synchrony and coordination between mother-infant touch to be fully captured. Findings from this dissertation were expected to enrich the scant knowledge of touch, fill important gaps, and have direct implications for early care practices and interventions.

Chapter 2: Dissertation Study 1

An intensive longitudinal investigation of maternal and infant touching patterns across context and throughout the first 9-months of life

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Manuscript submitted to *Infant Mental Health* and under review:

Mercuri, M., Stack, D.M., De France, K., Jean, A.D.L., & Fogel, A. (Under review). An intensive longitudinal investigation of maternal and infant touching patterns across context and throughout the first 9-months of life. *Infant Mental Health.*

Acknowledgements. The authors gratefully acknowledge financial support from le Fonds Québéçois de la recherche sur la société et la culture (FRQ-SC), Social Sciences and Humanities Research Council of Canada (SSHRC), Centre for Research in Human Development (CRDH), and Concordia University for grant support or funding awarded to Dale M. Stack (and co-investigators) and SSHRC, FRQ-SC, CRDH, and Concordia University for M.A. and doctoral level fellowships and support awarded to Marisa Mercuri. The authors would also like to gratefully acknowledge financial support from SSHRC, FRQ-SC, and Concordia University for M.A. and doctoral level fellowships and support awarded to Amélie D.L. Jean, and for post-doctoral level fellowships and support awarded to Kalee De France. This research was supported by grants to Alan Fogel from the National Institutes of Health and the National Institute of Mental Health. The authors would like to thank members of Dr. Stack's Infant and Child Studies Laboratory, including Gabrielle Schmitt, Emerald Walker, and Olivia Lazimbat, for their contributions toward behavioural observational coding and data preparation. Finally, the authors would like to thank the mothers and infants that participated in this study to whom we are deeply grateful.

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Abstract

Touch is a central component of mothers' and infants' everyday interactions and of the formation of a healthy mother-infant relationship. Despite research indicating the importance of touch across infancy, few studies have investigated maternal and infant touch simultaneously and longitudinally. As such, the present study was designed to examine the synchrony of mothers' and infants' various touching behaviours within and across their interactions over time.

The quantity (i.e., percent duration) and quality (i.e., type) of maternal and infant touching behaviours were examined among typically developing mother-infant dyads longitudinally at 1-, 3-, 5-, 7- and 9-months postpartum and within two normative interaction contexts, whereby infants were seated on their mothers' lap (1) and played freely on the floor with their mothers (2). Findings revealed that mothers' and infants' individual touch patterns, and the synchrony of mother-infant touch, varied according to the context of the dyadic interaction, the age of the infant, and the specific type of touch examined. At 1-month postpartum, mother-infant dyads coordinated their use of touch via behavioural matching; mothers and infants were especially reliant on rudimentary types of touch, including static (motionless) touch and stroking, which have soothing and regulatory properties. However, as infants aged to 9-months, dyads transitioned to a more complex form of tactile synchrony involving the parallel use of complementary types of touch (e.g., grasp, poke, pull). This evolution of tactile synchrony across the first 9-months of life may be explained by infants' growing behavioural repertoire and increased capacity to use more refined forms of touch. To our knowledge, this study was the first of its kind, uniquely contributing to the scant knowledge about the development of maternal and infant touch, filling some important gaps, and enriching our understanding about how and when tactile synchrony emerges within the mother-infant dyad.

Introduction

Touch represents the earliest, most fundamental mode of communication (Cascio et al., 2019; Stack, 2010; Field, 2019). For decades, researchers have highlighted the role of early contact behaviours such as touch in the formation of mother-infant bonding and attachment (Anisfeld & Lipper, 1983; Moore et al., 2007; Wiberg, 1990). Due to the fact that the somesthetic system is the first to develop, touch is regarded as the basis for all other forms of communication and represents a vital lifeline between mothers and infants (Heller, 2014; Hertenstein et al., 2006). Indeed, the tactile modality is implicated in essentially all aspects of the everyday lives of infants and has numerous integral functions (Heller, 2014), including those that are practical and utilitarian (e.g., to hold, clean, or feed infant), as well as those that are emotional (e.g., to demonstrate love and affection), nurturing (e.g., to comfort), regulatory (e.g., to regulate or soothe distress), stimulating (e.g., to play with infant), and communicative (e.g., to get mother's attention or signal specific needs) (Hertenstein et al., 2006; Jean & Stack, 2009; Mercuri et al., 2019; Stack, 2001; 2010). The importance of touch is further underscored by its link to physiological support systems, including cortisol production and heart rate variability, and peripheral and genetic biomarkers of the oxytocinergic system (Feldman et al., 2010; Feldman et al., 2012; Granat et al., 2017). Research investigating tactile stimulation via skin-to-skin contact (i.e., Kangaroo care) and massage during the neonatal period supports this notion (Beijers et al., 2016; Chen et al., 2017; Cleveland et al., 2017; Field, 2019) and has demonstrated numerous benefits in both typically developing and at-risk infants such as increased sleep quantity (Ferber & Makhoul, 2004), reduced crying (Erlandsson et al., 2007), and improved neurobehavioural stability (Montirosso & Provenzi, 2015). Despite the varied functions and advantages of touch with regard to infants' social, emotional, physical, and neurological growth, touch is the most understudied communicative modality and is often overlooked within the literature (Mantis et al.,

2019). Consequently, much remains unknown about how mothers and infants use touch to contribute to their interactions, and thus to their relationship as a whole.

Synchrony

Synchrony is one particular and noteworthy feature of mother-infant exchanges that may elucidate our understanding about the implications of touch in the formation of the mother-infant relationship (Guedeney et al., 2014; Leclère et al., 2014). Synchronous interactions entail continuous, temporal coordination and matching of behavioral and emotional states between partners (Hsu & Fogel, 2001; Leclère et al., 2014). Exchanges such as these involve mutual and reciprocal responsiveness between members of the dyad and require that both mothers and infants adapt to one another on a micro-behavioural level across modalities (Gordon & Feldman, 2008; Leclère et al., 2014). Synchrony provides a basis for the development of a secure mother-infant bond, as synchronous interactions during the first 9-months of life have been found to predict later secure attachment (Isabella & Belsky, 1991; Isabella et al.,1989). The benefits of synchrony also extend to more positive and healthy child outcomes (Leclère et al., 2014). For example, higher levels of behavioural synchrony during early mother-child exchanges have been linked to better child functioning, including more favorable cognitive and behavioural child outcomes (Ambrose & Menna, 2013), and have been shown to play a protective role in the development of mental health disorders (e.g., attention deficit hyperactivity disorder; Healey et al., 2010). Therefore, synchrony reflects the dynamic nature of mother-infant interactions and has marked advantages for their respective relationship and for the child's well-being.

Although the literature highlights the value of considering synchronic patterns on a micro-behavioural level and across all modes of communication, investigations to date have focused primarily on those pertaining to the visual (facial expressions, gaze) and vocal (vocalizations) modalities (Harder et al., 2015; Della Longa et al., 2020). While there have been

some studies which have explored synchrony within the tactile modality, most have considered the individual trajectories of maternal *or* infant touch alone (e.g., Babik et al., 2014; Chinn et al., 2019) and only few have conducted such examinations within the context of mother-infant interactions. For example, Feldman and colleagues (2010) examined only mothers' and not infants' touching behaviours during moments of shared mother-infant gaze, whereas Cuadros and colleagues (2019) examined the synchrony of body movement patterns among infant-unknown adult pairs. It should also be noted that much of the existing research pertaining to tactile synchrony within infancy has centered around infants' perceptions of synchronous stimulation and bodily-self-awareness (Crucianelli & Filippetti, 2020; Montirosso & McGlone, 2020). Recent evidence within this domain has revealed that infants are sensitive to interoceptive properties of affective touch, are able to detect and respond to synchrony via tactile stimulation and demonstrate a preference for synchronous visual–tactile stimulation (Della Longa et al., 2020; Jönsson et al., 2018). Though important and informative, such research does not add to our understanding about how mothers and infants jointly achieve synchrony through touch themselves, and how this may unfold across their interactions over time. Thus, the synchronic patterns produced by mothers and infants through touch, as well as the development of tactile synchrony within the mother-infant dyad, are not yet well understood. This represents a significant area of investigation to pursue given the pervasiveness of maternal and infant touch throughout the vast majority of mother-infant interactions (Field, 1984; Jean et al., 2009; Stack & Muir, 1990).

Limitations of the Extant Touch Literature

The explanation for our insufficient knowledge of touch – in general and specifically with regard to synchrony – goes well beyond the mere paucity of research on the tactile modality and is tied to a number of key limitations in the existing research. First, investigations of mother-

infant touch to date have been largely unidirectional, examining *either* maternal *or* infant touch rather than both (Mantis et al., 2019). However, theoretical models of development call for investigations that equally capture how *both* members of the dyad contribute to their interactions (DiCorcia & Tronick, 2011). The dynamic systems perspective posits that mothers and their infants form a mutually regulated bidirectional system (Fogel, 1992). The mutual regulation model similarly views mothers and infants as an integrated, dyadic system, and recognizes their interactions as a collective exchange of communicative signals (Tronick, 1989; Tronick & Weinberg, 1997). That is, both members of the dyad are considered sensitive and responsive to changes in one another's behavioural and emotional displays, each actively shaping the progression of their social exchange (Gianino & Tronick, 1988; Montirosso et al., 2010; Weinberg et al., 2006). Yet, the few studies that have investigated touch from these perspectives and in relation to synchrony have solely assessed maternal touch, and only in conjunction with infant gaze or emotional expression (e.g., Granat et al., 2017; Feldman et al., 2010). Despite the fact that touch is the most developed of all senses (Field, 2010), infants' most relied-upon communicative modality (Kaye & Fogel, 1980), and infants' very first and most primary means of contact (Gallace & Spence, 2016), it appears that infant tactile behaviours have been neglected at least within bidirectional research designs. Explorations that examine variations in both partners simultaneously and particularly within the tactile modality are crucial to understand whether, and to what extent, touch may be used to achieve coordinated, symmetrical, and synchronous interactions.

Second, investigations of touch have been predominantly cross-sectional rather than longitudinal thus far (Davis et al., 2018). As such, few studies (exceptions include e.g., Jean et al., 2009; Mercuri et al., 2019) have investigated the developmental course of touch using longitudinal designs (Doi et al., 2011). Yet, as the infant's motor abilities continue to develop

with age, both the infant's and mother's touching behaviors, as well as their corresponding levels of synchrony, are expected to evolve over time. The first 9-months of life are particularly meaningful and are regarded as a sensitive period warranting further assessment (Feldman, 2015). Touch plays a crucial role in mother-infant exchanges during this span of time, and the synchrony experienced throughout these initial 9-months are linked to long-lasting effects on infants' social and emotional development (Feldman, 2015; Granat et al., 2017). Consequently, longitudinal designs of touch across this critical period are central and essential to our understanding of the typical progression of tactile synchrony within the context of the mother-infant relationship (Widom et al., 2004).

Third, few investigations have considered touch within and across more naturalistic settings. Experimental research designs provide useful information about how mothers and infants adapt and respond to particular challenges (e.g., violation of social norms via the classic Still-Face procedure developed originally by Tronick et al., 1978; still-face with touch procedure as in Stack & Muir, 1990; 1992). However, these designs reveal little about how touch is used in more typical or everyday interactions, which ultimately represent the large majority of mother-infant exchanges. Even when employed within laboratory settings, these more typical face-to-face interactions can vary widely with regard to contextual factors, including mothers' and infants' positioning (Jean et al., 2009; Lavelli & Fogel, 2002) as well as the characteristics of the surrounding environment (e.g., presence of toys; Field, 2019). As stated by Hertenstein and colleagues (2006), communication always occurs within a context and each communicative modality must be understood according to the given context. Further investigation of more naturalistic mother-infant exchanges that consider contextual factors is thus warranted. Additionally, investigations of the same dyads across multiple naturalistic settings are needed to

achieve a more holistic understanding of how mothers and infants regularly use touch to achieve synchrony.

Finally, descriptions of touch have been ambiguous and relatively undefined, as researchers continue to use broad categorizations of touch without necessarily specifying the individual and discrete touching behaviours that make up such constructs (Field, 2010). For example, the use of terms such as "overall" or "total" touch are prevalent, yet falsely relay that touch is a simplistic, one-dimensional construct. Global constructs such as affectionate, stimulating, or instrumental touch (Ferber et al., 2008; Moszkowski et al., 2009; Stack, 2010) are slightly more defined, but still reveal little about the range of specific touching behaviours both mothers and infants display (e.g., stroking, rubbing, tickling). The use of global constructs may also be problematic given that they are often defined and measured inconsistently across studies. Given that touch is a dynamic, complex, and multidimensional modality, investigations must describe the various types of touching behaviours, and the varying lengths of time displayed for each (Hertenstein, 2002). Although few, there are some exceptions (see for example, Crucianelli et al., 2019; Ferber et al., 2008; Jean et al., 2009; Mantis et al., 2019; Mercuri et al., 2019; Moszkowski et al., 2009; Stack & Muir, 1990) where the individual types of touch have been examined. These more specific investigations better capture variations in the quantity and quality of touch during mother-infant interactions, provide more comprehensive descriptions of touch, and consequently, allow for more meaningful comparisons of findings across studies.

The Present Study

The current study was designed to address each of these significant gaps within the literature in a longitudinal design with 5 time points. The first objective was to investigate the development of maternal and infant touch across time and interaction context. Particularly, the quantity (duration) and quality (type) of *both* mothers' and infants' *specific* touching behaviours

were examined longitudinally at 1-, 3-, 5-, 7-, and 9 -months, and during two kinds of naturalistic mother-infant interactions: 1) free play on the floor with toys, and 2) proximal face-to-face interaction with infants positioned on their mothers' laps. The second objective was to investigate tactile synchrony across these same mother-infant exchanges, and to determine the natural progression of tactile synchrony across the first 9-months of life. Therefore, the overall aim of the present study was to obtain a more complete understanding of how maternal and infant touch typically develop, and how touch may be used to achieve synchrony during early naturalistic mother-infant interactions.

Method

Participants

This study was conducted in accordance with the ethical standards of the American Psychological Association, and after approval by the institutional ethics review board at the University of Utah. Following ethics review and approval, mothers provided their informed consent (see Appendix A for consent form). Twelve mothers and their full-term infants from a Midwestern community in the USA participated in the current study. Eight infants were male, and four were female. All infants were born full term, had no major birth complications, and came from intact middle-class families. Mothers were aged 21 years and older. While the minimum level of education among mothers corresponded to a high school diploma, nearly all obtained a bachelor's degree. All mothers were White, with the exception of one mother, who was African American (Jean et al., 2009; Hsu & Fogel, 2001; 2003).

Procedure

Dyads were videotaped at five different time points. Time 1 occurred when infants were approximately 1-month old (4 to 6 weeks), Time 2 when infants were 3-months-old (13 to 15 weeks), Time 3 when infants were 5-months-old (22 to 23 weeks), Time 4 when infants were 7-

months-old (28 to 29 weeks), and finally, Time 5 when infants were 9-months-old (34 to 35 weeks). These specific ages were selected in the current study because infants have been found to be effective communicators through touch, and highly responsive and sensitive to their mothers, during interactions across this period of time (Kaye & Fogel, 1980). Furthermore, the first 9-months of life has been deemed a sensitive period with regard to synchrony and development (Feldman, 2015). This intensive longitudinal research design allowed for a thorough examination of the progression of touch and synchrony within the mother-infant dyad.

For all five time points, mothers and their infants engaged in two 5-minute face-to-face interactions. Mothers were instructed to interact with their infants as they normally would, first while being positioned on the floor with their infant and age-appropriate toys (Floor context), and then seated on a chair with their infant on their lap (Lap context). Although these interactions took place in a laboratory setting, they can be characterized as naturalistic given that the format, including the length of the interaction, the positioning of the dyad, and the characteristics of the surrounding environment (i.e., presence of toys, absence of experimenters in the room), are representative of typical, everyday mother-infant exchanges. Additionally, the specific length of each mother-infant interaction (i.e., 5-minutes) is congruent with the extant literature (Feldman, 2002; Ferber et al., 2008; Jean et al., 2009; Moreno et al., 2006).

Video recordings were reviewed for behavioral coding using a professional software system for behavioral research, Mangold INTERACT, which allows live second-by-second qualitative and quantitative analysis of multimedia data. Maternal touch was coded using the Caregiver-Infant Touch Scale (CITS; Jean et al., 2009; Stack, 2010; Stack et al., 1996), and infant touch was coded using the Infant Touch Scale (ITS; Moszkowski & Stack, 2007). Both systems are reliable and systematic measures of the second-by-second changes in qualitative and quantitative aspects of tactile communication.

Coders were first trained on the coding systems to reach a high level of reliability before formal coding commenced. When discrepancies between raters occurred during this training period, coders reviewed the corresponding portion of the video second-by-second, discussed, and deliberated the appropriate code for the specific segment on the video, and subsequently re-coded that portion of the video with the mutually agreed upon category. Inter-rater reliability was subsequently conducted between coders (one of the coders was blind to the hypotheses of the study) and determined using kappa coefficients for 30% of randomly chosen video recordings of mother-infant interactions. A high inter-rater reliability was determined for both the CITS (k = .90) and the ITS (k = .92) overall and for the individual touching behaviours within each coding system (k = .75 to .96).

Data preparation

Percent durations for each type of touch were used as the dependent variables for each of the analyses (described below) and these refer to the percentage of time allocated to a particular type of touch. These were calculated by dividing the raw duration of a specific touching behavior by the length of the corresponding interaction period (and multiplied by 100). As such, percent durations control for any slight differences in the length of the interaction periods at each interaction time point or context, both within and across dyads (Herrera et al., 2004).

Type of touch included the overlapping categories of touching behaviours coded between the CITS and ITS (see Table 1; note that some labels for individual types of touch were condensed within the text). For a portion of the analyses, specific touching behaviors were categorized more generally, as either playful/stimulating or affectionate/nurturing (see Table 1). Playful/stimulating touch included touching behaviors that were more engaging and faster paced whereas affectionate/nurturing touch included those types of touch that were less stimulating and

slower paced. In line with Mantis et al. (2019), these global categorizations were developed using a systematic step-by-step process which integrated information obtained from behavioral observations of mother-infant face-to-face interactions, previous coding systems developed in our research laboratory, relevant research literature, and a factor analysis. Further, previous investigations utilizing this categorization have yielded meaningful findings (i.e., Mantis et al., 2019; Moreno et al., 2006; Moszkowski & Stack, 2007; Moszkowski et al., 2009).

Statistical analyses

Analyses of variance: Maternal and infant touch across time and context

A series of three-way mixed analyses of variance (ANOVA) were conducted to determine differences between mothers and infants with regard to their individual touching behaviours, and as a function of time and context. This statistical approach is consistent with previous studies within the literature assessing maternal and infant touch (e.g., Jean et al., 2009, Mantis et al., 2019, Mercuri et al., 2019). For each analysis, partner (Mother, Infant) was the between subjects variable, and both context (Floor, Lap) and time (Time 1, 2, 3, 4, and 5) were the within subjects variables. The percent duration of general and specific types of touch displayed by mothers and their infants were entered as dependent variables.

Statistically significant main effects and interactions resulting from the ANOVA analyses were followed up with post hoc tests in order to isolate the source of the significance. Bonferroni corrections were performed to reduce the occurrence of Type 1 errors (Mantis et al., 2019). Statistically significant findings pertaining to this set of analyses are predominantly reported in the text below. Partial eta squared (η_p^2) was reported as a measure of effect size.

Correlations and multilevel modeling: Mother-infant synchrony

Pearson correlations were conducted to examine the association between mothers' and infants' touching behaviours; these provided estimates, including the average magnitude and

direction, of the synchrony between maternal and infant touching behaviours at one point in time (and thus within one context). The use of correlational analyses as a method of assessing concurrent forms of parent-child synchrony is supported by previous research (Davis et al., 2018; Helm et al., 2018).

Additionally, multilevel modeling (MLM) procedures were used to assess longitudinal forms of mother-infant synchrony (i.e., dynamic, and dyadic, associations between mother and infant touching behaviours; Creaven et al., 2014). That is, correlated slopes analyses (type of MLM procedure) were used to determine the degree to which members of the dyad followed a similar pattern of change over time (Helm et al., 2018). Slopes representing individuals' patterns of change across repeated measures were calculated and then correlated across dyads. A series of correlated slope analyses were conducted to examine whether changes in maternal touching behaviours were associated with changes in infant touching behaviours across time and for each of the two interactive contexts. According to Davis and colleagues (2018), MLM is the most frequently implemented statistical approach for examining synchrony within parent-child dyads. These analyses have been commonly applied to assess physiological synchrony among parent-child dyads but, to our knowledge, have yet to be extended to tactile synchrony.

Analyses (ANOVAs, Pearson correlations, and MLM/correlated slopes) were conducted for each of the specific yet overlapping touching behaviours (e.g., Static touch), as well as for the more global categories of touch (e.g., Affectionate/Nurturing; see Table 1). Across analyses, results were considered statistically significant at a critical alpha level of .05.

Results

Data integrity

Data were screened for integrity and to ensure that the assumptions of each set of analyses were met. The data cleaning process involved checking for outliers, or scores more than

3 standard deviations away from the mean. Standardized scores were used to identify outliers. Outliers were retained and adjusted by changing their values to the next highest score (Kline, 2009; Tabachnick & Fidell, 2001). ANOVAs and Pearson correlations were conducted using the Statistical Package for Social Sciences (SPSS, version 26.0), whereas MLMs were conducted using Mplus (version 8.4).

Objective 1: To investigate the development of maternal and infant touch across time and interactive context

Global Types of Touch:

Affectionate/Nurturing

A 2x2x5 mixed ANOVA was conducted to investigate the effects of partner, context, and time on the percent duration of Affectionate/Nurturing touch. Results revealed a significant three-way interaction, F (4, 96) = 25.74, p = .000, η_p^2 = .518.

In the Floor context, mothers showed a significant increase in the percent duration of Affectionate/Nurturing touch from Time 1 (M = 16.66, SE = 4.49) to Time 5 (M = 89.50, SE = 1.69), whereas infants demonstrated a significant decrease in Affectionate/Nurturing touch from Time 1 (M = 73.72, SE = 4.49) to Time 3 (M = 9.98, SE = 4.32) and maintained low levels of this type of touch to Time 5 (M = 5.19, SE = 1.69).

In the Lap context, mothers maintained moderate levels of Affectionate/Nurturing touch from Time 1 (M = 57.31, SE = 4.61) to Time 3 (M = 53.04, SE = 3.29), followed by a significant decrease at Time 4 (M = 5.72, SE = 4.50) and a subsequent significant increase at Time 5 (M = 72.19, SE = 5.25), whereas infants demonstrated a general decrease from Time 1 (M = 65.11, SE = 4.61) to Time 5 (M = 30.63, SE = 5.25). Refer to Table 2 for the means and standard errors, and to Figures 1 and 2 for visual depictions of these results.

Playful/Stimulating

A 2x2x5 mixed ANOVA was conducted to investigate the effects of partner, context, and time on the percent duration of Playful/Stimulating touch. Results revealed a significant three-way interaction, F (4, 96) = 7.22, p = .000, η_p^2 = .231.

In the Floor context, mothers maintained low levels of Playful/Stimulating touch from Time 1 (M = 15.91, SE = 3.90) to Time 5 (M = 5.18, SE = 3.76), whereas infants demonstrated a significant increase in this touch from Time 1 (M = 8.97, SE = 3.90) to Time 3 (M = 62.10, SE = 4.90), and maintained the same moderate levels of touch to Time 5 (M = 60.72, SE = 3.76).

In the Lap context, mothers slightly increased the percent duration of Playful/Stimulating touch from Time 1 (M = 21.45, SE = 3.45) to Time 3 (M = 34.67, SE = 4.26), followed by a decrease at Time 5 (M = 16.78, SE = 5.64), whereas infants steadily increased their use of this type of touch from Time 1 (M = 5.79, SE = 3.45) to Time 5 (M = 46.41, SE = 5.64). Refer to Table 2 for the means and standard errors, and to Figures 1 and 2 for visual depictions of these results.

Individual Types of Touch:

Static

A 2x2x5 mixed ANOVA was conducted to investigate the effects of partner, context, and time on the percent duration of Static touch (a specific type of Affectionate/Nurturing touch). Results revealed a significant three-way interaction, F (4, 96) = 12.83, p = .000, η_p^2 = .348.

In the Floor context, mothers generally maintained low levels of Static touch from Time 1 (M = 8.95, SE = 3.66) to Time 5 (M = .61, SE = .87), whereas infants demonstrated a significant decrease in Static touch from Time 1 (M = 61.41, SE = 3.66) to Time 3 (M = 5.43, SE = 3.89) and maintained very low levels of this touch across time to Time 5 (M = 3.67, SE = .87).

In the Lap context, mothers increased their use of Static touch from Time 1 (M = 37.34, SE = 4.27) to Time 3 (M = 49.25, SE = 2.97), followed by a significant decrease at Time 4 (M = 3.77, SE = 4.51) that was maintained at Time 5 (M = 1.85, SE = 2.07). Comparatively, infants in the Lap context decreased their use of Static touch from Time 1 (M = 52.63, SE = 4.27) to Time 3 (M = 17.78, SE = 2.97) and maintained similar, relatively low levels of Static touch across time to Time 5 (M = 22.19, SE = 2.07; see Table 3).

Stroke/Caress

A 2x2x5 mixed ANOVA was conducted to investigate the effects of partner, context, and time on the percent duration of Stroke/Caress (a specific type of Affectionate/Nurturing touch; includes Rub/Massage and Wipe). Results revealed a significant three-way interaction, F (4, 96) = 8.55, p = .001, η_p^2 = .263.

In the Floor context, mothers maintained very low levels of Stroke/Caress from Time 1 (M = 3.69, SE =1.01) to Time 4 (M = 1.21, SE = .30), followed by a significant increase at Time 5 (M = 88.52, SE = 1.44). In this same context, infants demonstrated a slight increase of Stroke/Caress from Time 1 (M = 7.35, SE = 1.01) to Time 2 (M =12.29, SE = 1.74), and then decreased their use of this touch from Time 3 *(*M = 3.85, SE = 1.20) to Time 5 (M = .53, SE = 1.45).

In the Lap context, mothers gradually decreased their use of Stroke/Caress from Time 1 (M = 8.55, SE = 1.63) to Time 4 (M = 1.04, SE = .35), and then significantly increased their displays of this touch at Time 5 (M = 69.73, SE = 5.34). Infants within the Lap context demonstrated low levels of Stroke/Caress and reduced their use of this touch from Time 1 (M = 12.06, SE = 1.63) to Time 5 (M = .90, SE = 5.34; see Table 3).

Pat/Tap

A 2x2x5 mixed ANOVA was conducted to investigate the effects of partner, context, and time on the percent duration of Pat/Tap (a specific type of Affectionate/Nurturing touch). Results revealed a significant three-way interaction, F (4, 96) = 9.03, p = .000, η_p^2 = .273.

In the Floor context, mothers decreased their use of Pat/Tap from Time 1 (M = 4.03, SE = 1.76) to Time 5 (M = .37, SE = .26). Infants similarly decreased their use of Pat/Tap from Time 1 (M = 4.96, SE = 1.76) to Time 5 (M = .99, SE = .26) within the Floor context.

In the Lap context, mothers decreased their use of Pat/Tap from Time 1 (M = 11.43, SE = 2.52) to Time 5 (M = .61, SE = 1.07), whereas infants increased their use of this touch from Time 1 (M = .42, SE = 2.52) to Time 4 (M = 8.15, SE = 2.03) and maintained about the same rates to Time 5 (M = 7.54, SE = 1.07; see Table 3).

Grasp

A 2x2x5 mixed ANOVA was conducted to investigate the effects of partner, context, and time on the percent duration of Grasp (a specific type of Playful/Stimulating touch; includes Squeeze/Pinch and Clutch/Clasp). Results revealed a significant three-way interaction, F (4, 96) = 4.87, p = .001, η_p^2 = .169.

In the Floor context, mothers maintained low levels of Grasp from Time 1 (M = 2.10, SE = 1.34) to Time 5 (M = 3.70, SE = 3.54). Contrarily, infants demonstrated low levels of Grasp at Time 1 (M = 3.70, SE = 1.34) in the Floor context, which was followed by significant increases at Time 2 (M = 21.92, SE = 3.94) and Time 3 (M = 61.83, SE = 4.75), and then a slight decrease at Time 4 (M = 51.10, SE = 4.59) which was maintained to Time 5 (M = 45.76, SE = 3.54).

In the Lap context, mothers maintained very low levels of Grasp from Time 1 (M = 3.54, SE = 1.11) to Time 3 (M = 4.75, SE = 3.95), followed by a significantly increase at Time 4 (M = 23.01; SE = 5.03) and then a decrease at Time 5 (M = 12.13; SE = 5.09); infants maintained

similar low levels of Grasp from Time 1 (M = 5.11, SE = 1.11) to Time 2 (M = 8.84, SE = 1.64), followed by a significant increase from Time 3 (M = 25.14, SE = 3.95) to Time 5 (M = 38.81, SE = 5.09; see Table 3).

Pull/Lift

A 2x2x5 mixed ANOVA was conducted to investigate the effects of partner, context, and time on the percent duration of Pull/Lift (a specific type of Playful/Stimulating touch; includes Clap/Extension and Push). Results revealed a significant three-way interaction, F (4, 96) = 3.84, p = .006, η_p^2 = .138.

In the Floor context, mothers demonstrated moderate amounts of Pull/Lift at Time 1 (M = 10.63, SE = 3.26) and then decreased their use of Pull/Lift from Time 2 (M = 5.10, SE = .67) to Time 5 (M = .03, SE = 1.32). Infants in the Floor context maintained very little to no amount of Pull/Lift from Time 1 (M = 1.07, SE = 3.26) to Time 3 (M = .22, SE = .51), followed by increases at Time 4 (M = 6.00, SE = 1.23) and Time 5 (M = 13.24, SE = 1.32).

In the Lap context, mothers increased their use of Pull/Lift from Time 1 (M = 17.58, SE = 2.88) to Time 3 (M = 26.69, SE = 1.98), and then decreased their use of this touch to Time 5 (M = .62, SE = .85). Infants in the Lap context essentially did not use Pull/Lift from Time 1 (M = .00, SE = 2.88) to Time 4 (M = .05, SE = 1.46) but minimally increased this touch at Time 5 (M = 2.25, SE = .85; see Table 3).

Objective 2: To investigate tactile synchrony during mother-infant interactions across the first 9-months of life

Floor Context

Pearson correlations revealed that increases in maternal Poke/Prod were associated with increases in infants' Poke/Prod at Time 1 only (r =.60; p = .031).

Correlated slopes analyses (i.e., MLM procedures) revealed increases in maternal Grasp over time were associated with decreases in infant Static touch (b = -3.87, SE = .59, p =.000). Increases in infant Static touch over time were also associated with increases in maternal Stroke/Caress (b = .16, SE = .07, p =.028).

Lap Context

Pearson correlations revealed that, on a bivariate level, increases in maternal Pat/Tap were associated with increases in infant Pat/Tap at Time 1 only (r =.57, p =.040).

Correlated slopes analyses (i.e., MLM procedures) revealed that increases in maternal Stroke/Caress over time were associated with increases in infant Stroke/Caress (b = 2.68, SE = .61, p =.000). Additionally, increases in maternal Pull/Lift over time were associated with increases in infant Grasp (b = .24, SE = .11, p =.024).

The remaining combinations of maternal and infant touching behaviours across each of the two interactive contexts, including the more global categories of touch (Affectionate/Nurturing and Playful/Stimulating), did not yield statistically significant results (p>.05).

Discussion

The present study investigated how mothers and infants use touch to contribute to their typical dyadic interactions and to achieve synchrony across the first 9-months postpartum. Despite the pervasiveness of touch during early mother-infant interactions, and the profound role it can play in synchrony and infant development, existing research on the tactile modality has been scarce and incomplete. The current study was formulated to address the numerous gaps in the literature pertaining to touch and synchrony, foundational components of the mother-infant relationship. To our knowledge, this study was the first to employ an intensive longitudinal design consisting of five time-points and two interactive contexts to examine more general *and*

specific touching behaviours of *both* mothers and infants. Results from the present study add to the movement toward multidimensional, bidirectional, and longitudinal investigations of mother-infant touch and thus the study represents an important step forward within the literature.

Mother-Infant Touch Across Time and Context

The first objective was to investigate the development of maternal and infant touch across time and interaction context. Our findings indicated that the typical trajectory of mothers' and infants' touch over time varied according to the type of touching behaviour as well as the context of their interactions. Regarding infant touch in the floor context, infants demonstrated high levels of affectionate/nurturing touching behaviours, including static touch, at 1-month but decreased their use of this touch to very low levels from 5- to 9-months postpartum. Infants demonstrated the reverse in terms of playful/stimulating touch within the floor context, as they initially displayed low levels of this touch at 1-month and increased it to relatively high levels at 5-months and onward to 9-months postpartum. In the lap context, infants demonstrated a general decrease from high to moderate levels of affectionate/nurturing touch, as well as static touch, over time. Within this same context, infants demonstrated a general increase in playful/stimulating touch. Specifically, a substantial increase in infant grasping was observed from 1-to 5-months postpartum in the lap context (4% to 62%), which is consistent with prior research demonstrating the emergence of grasping throughout the first 6-months of life (Thomas et al., 2015). Given that our study was the first (to our knowledge) to assess the gradual progression of infant touch from 1- to 9-months of age, our ability to make comparisons with findings from previous studies was rather limited. However, the patterns of infant touch described here are consistent with previous research indicating that mother-infant interactions become more playful with age (Field, 2010) and reflect how infants become increasingly

engaged and active during their interactions over the course of the first year of life (Evans & Porter, 2009).

The range and considerable rates of touching behaviours displayed by infants aged as young as 1-month provide further support for the notion that touch is the first and primary communicative modality to develop (Montagu, 1986; Rubin, 1963). Instances in which infants spent significantly more time using touch than their mothers also demonstrate infants' initial reliance on touch as a means of communicating. For example, infants displayed significantly more static touch than their mothers (61% vs. 9%, respectively) at 1-month postpartum within the lap context, underscoring their desire to maintain tactile contact very early on in infancy. Hence, infants are particularly reliant on *rudimentary* types of tactile behaviours, and not just touch in general, in the first month of life. However, the gradual decreases in certain types of touch demonstrated by infants as they age (e.g., affectionate touching behaviours) may be indicative of the emerging complexity of mother-infant communication as well as infants' enhanced capacity to utilize and integrate behaviours tied to the visual and vocal modalities rather than touch alone (Ferber et al. 2008; Hsu & Fogel, 2001).

In contrast, mothers are already equipped with behaviours from other modalities and can effectively utilize and integrate touch with other modes of communication; this may explain why mothers in the present study exhibited more variable rates of touch. Indeed, results revealed that maternal affectionate/nurturing and playful/stimulating touch in the lap context, including more specific types such as static touch, stroke/caress, and pull/lift, were quite varied and vacillated across the five time points. However, in the floor context, mothers increased their use of affectionate/nurturing touch over time; they initially demonstrated low levels at 1-month postpartum and later utilized high levels at 9-months. Notably, mothers' use of stroke/caress significantly increased from 7- to 9-months postpartum, specifically from 1% to 70% in the lap

context, and from 1% to 88% in the floor context. These findings reflect the important developmental milestones that tend to occur around 9-months postpartum. At this time, infants tend to be more mobile and excitable and are expected to have more refined motor abilities, allowing them to pick objects up, stand and sit without support, and crawl (Centers for Disease Control and Prevention [CDC], 2021; Chen et al., 2007). Furthermore, infants become more object focused from 6- to 12-months of age (Sera et al., 2020). The developmental milestones at 9-months suggest that a transition occurs regarding the nature of mother-infant interactions at this time; across both contexts, interactions become increasingly characterized by infant activity and movement. Consequently, mothers may be more likely to respond with soothing and regulatory types of behaviours such as stroke/caress as a means of regulating infant arousal as well as attending to their infants and demonstrating affection during play (Mantis et al., 2019). Contrarily, mothers maintained very low levels of playful/stimulating touch, including the pull/lift category of touch, in the floor context across time. Given that the floor context consisted of toys and increased opportunity for infant activity and movement, this decrease in maternal touch suggests that mothers adapted their use of touch to the increased mobility of their 9-month-old infants and provided them with the space and freedom to crawl or play. The more distal positioning of the floor context may have also fostered increased reliance on behaviours from the visual and vocal modalities, which can be more easily implemented while mothers onlook and interact with their infants from afar. Such findings are consistent with Serra and colleagues (2020), who found that mothers spend less time touching their 12-month-old infants within the context of a free play with toys (in line with the present study), as compared to challenging or playful interactions without toys.

Our results somewhat deviate from those reported by Ferber and colleagues (2008), which despite being dated, is the most comparable investigation within the extant literature. They

examined the developmental trajectories of maternal touch during natural caregiving and play sessions among healthy mother-infant dyads at 3-, 6-, 9-, and 12-months postpartum using a cross-sectional research design. They found that the frequency of maternal affectionate and stimulating (i.e., playful) touch significantly and gradually decreased during the second 6-months of life. Across studies, the trajectories of maternal touch appear to vary according to the specific developmental period (1- to 9-months in the present study vs. 3- to 12-months in Ferber et al., 2008), the context and format of the interaction, and perhaps most notably, the dimension (i.e., frequency) of touch. Indeed, we examined the proportion of time (i.e., duration) mothers displayed touch, whereas Ferber and colleagues (2008) examined the number of times (i.e., frequency) mothers displayed touch. While mothers may demonstrate fewer touching behaviours as their infants age (Ferber et al., 2008), they spend more time engaged in certain types of touch throughout their more proximal interactions with their infants across time. Therefore, the results of the present study underscore the value of following the same dyads over time and illustrate that maternal touch may not necessarily have a general decline across the first year of life as Ferber and colleagues (2008) suggest in their comparison of different dyads across time via their cross-sectional investigation. Instead, mothers' use of touch may become more fluid and continuous in its presentation as mothers become more comfortable and familiar with caregiving strategies. The partial discordance between our findings and those of Ferber and colleagues (2008) further demonstrate the implications of longitudinal research designs while highlighting the complex and multifaceted nature of the tactile modality and underscoring duration as a meaningful parameter of touch (Herstenstein, 2002; Mantis et al., 2019; Mercuri et al., 2019; Moreno et al., 2006; Stack, 2010; Stack & Jean, 2011).

Mother-Infant Touch Synchrony

The second objective was to investigate tactile synchrony across these same mother-infant exchanges, and to determine the natural progression of tactile synchrony across the first 9-months of life. This represents a substantial contribution to the literature considering that there have been no studies to date which have examined tactile synchrony in a manner that captures dynamic changes in both maternal *and* infant touch. Previous studies exploring the concept of tactile synchrony have either failed to examine infant touch altogether (e.g., Feldman et al., 2010), or have neglected to examine infant touch during mother-infant interactions (Cuadros et al. 2019; Della Longa et al., 2020), consequently overlooking the bidirectionality of touch and the context (e.g., setting of interaction, positioning of dyad) most likely to foster synchrony. Findings within the current investigation revealed that in the lap context, increases in mothers' use of stroke/caress were associated with increases in infants' use of this same type of touch over time. However, in the floor context, increases in mothers' use of stroke/caress were associated with increases in infants' use of static touch over time. These patterns suggest that mothers and infants use soothing and regulatory tactile behaviours in tandem, across context and age. Additionally, increases in mothers' use of pull/lift were associated with increases in infants' use of grasp in the lap context from 1- to 9-months postpartum. Such an association is intuitive considering that grasping is a reflexive behaviour exhibited by infants when being pulled or lifted, thereby facilitating mothers' attempts to re-position infants while placed on their laps. Mothers and infants were also found to use pat/tap similarly in the lap context, and poke/prod similarly in the floor context, specifically at 1-month postpartum. Thus, it appears that behavioural matching is more likely to occur between maternal and infant touch earlier on in infancy. As mother-infant communication evolves and infants' capacity to use touch becomes more sophisticated, mothers and infants subsequently develop a form of tactile synchrony that goes beyond the simultaneous use of the very same touching behaviours and transitions to the

parallel use of complementary types of touch. Although previous research has cited that mother-infant synchrony first emerges at 3- and 4-months postpartum (Bell, 2020; Feldman, 2012; Northrup & Iverson, 2020), our findings reveal that tactile synchrony emerges as early as the first month of life. To date, tactile synchrony has not been well understood as investigations have focused primarily on the visual and vocal modalities (Harder et al., 2015; Northrup & Iverson, 2020). As such, the results of the present study represent a valuable contribution to the literature by describing synchronous tactile patterns among mother-infant dyads, and uniquely uncover the transition from matching toward complementary patterns of mother-infant touch across the initial 9 months of infancy.

Implications, Limitations, and Future Directions

Findings elucidate the central role of touch as it pertains to our knowledge about the progression of mother-infant synchrony. Since touch is the first communicative modality to develop (Gallace & Spence, 2016) and is regarded as the foundation of all other forms of communication (Heller, 2014; Hertenstein et al., 2006), it is conceivable that tactile synchrony may be the most primitive form of synchrony. In line with the findings from the first objective, this second set of results illustrates that the development of synchrony may be rooted in rudimentary types of touch such as static touch, stroke/caress, pat/tap, and grasp (in addition to the corresponding behaviours tied to these individual types; see Table 1). The early progression of tactile synchrony appears to be intrinsically tied to tactile behaviours that are innate and primal, which are observed both in utero and shortly after birth (Hata, 2016), and not necessarily all touching behaviours or touch in general. Our findings suggest that infants are better able to coordinate more basic forms of touch with maternal touch, whereas more complex forms of touch likely require more time (i.e., beyond 9-months postpartum) to reach a level of development that enables dyadic synchrony. Indeed, infants show more refined fine motor

coordination and responses, and better visual motor coordination in the second 6-months of life (Field, 2010; Lavelli & Fogel, 2005). It is important to note that global measures of touch (i.e., playful/stimulating and affectionate/nurturing categories) did not yield significant results with regard to synchrony in the current study. As such, it is possible that overarching categories of touch conceal the specificity of tactile synchrony across mother-infant interactions. Findings therefore highlight the importance of considering the multidimensional and dynamic nature of touch and call for future research to pursue more comprehensive and detailed investigations of the tactile modality which examine individual touching behaviours. Future research may expand on the current findings by examining other more specific touching behaviours that occur through other areas of the body rather than the hands, including whole body-contact behaviours implicated in mother-infant attachment and bonding such as cuddling (Barry, 2019).

Future research should also consider the development of tactile synchrony among at-risk dyads (e.g., depressed mothers, infants born prematurely or at a very low birth weight), as the current study focused solely on typically developing low-risk dyads. It is imperative to investigate at-risk populations as such dyads have been found to demonstrate impaired regulatory abilities and atypical exchanges (e.g., Mantis & Stack, 2018) and are thus likely to exhibit different trajectories of touch and synchrony than those described here. Furthermore, future investigations should seek to replicate our findings with a larger sample size, enhancing generalizability and addressing a limitation of the present study. Indeed, the sample size in the present study was quite small given the intensive research design employed and the practical limitations tied to infant research (Brzozowska et al. 2021; Mantis et al., 2019). However, the present sample size is consistent with microanalytic studies aimed at thoroughly describing the dynamics of parent-infant interactions using intensive observational methods (e.g., Beebe, 2006; DiMercurio et al., 2018; Jean et al., 2009; Stefana et al., 2020). Finally, future research should

continue to explore the development of tactile synchrony across different interactive contexts, and within alternative dyadic systems that include fathers and other primary caregivers, and with an expanded age range (Jean et al., 2009; Mercuri et al., 2019).

Conclusions

Taken together, the results derived from our study uniquely contribute to the scant knowledge about the development of maternal and infant touch and enrich our understanding about *how* and *when* tactile synchrony emerges within the mother-infant dyad. Findings meaningfully add to the dearth of literature on touch and suggest that the development of synchrony may be rooted in rudimentary types of touch. Our results also highlight the inherent functions underlying the tactile modality, especially the regulatory and playful functions of touch (Field, 2019; Jean & Stack, 2009; Moszkowski et al., 2009; Stack, 2010) and may thus be a mechanism underlying interpersonal synchrony during early mother-infant interactions. Results from the present study underscore the importance of examining contextual factors by revealing how maternal and infant touch patterns vary within two interactive yet naturalistic contexts. The numerous pronounced benefits of both touch and synchrony regarding infants' physiological and psychological health and well-being, as well as the formation and development of the mother-infant relationship, have critical implications for early care practices and parenting intervention programs.

Table 1. *Behavioural observational coding systems and adaptations for maternal and infant touch in the present study.*

	Coding System		
	Caregiver-Infant Touch Scale (CITS); Stack et al., 1996; Jean et al., 2009	**Infant Touch Scale (ITS);** Moszkowski & Stack, 2007	
Global Touch Category	***Specific Touch Category***		***Brief Description***
Affectionate/ Nurturing	1.Static	1.Static	Touch without movement (coded independent of holding given the positioning of the lap context).
	2.Stroke/Caress/Rub/ Massage	2.Stroke/Caress/Rub/Wipe	Lateral soft and gentle movements or rubbing motion involving strong back and forth or circular movements.
	3.Pat/Tap	3.Pat/Tap	Quick up and down motions using either palm or fingertips.
Playful/ Stimulating	4.Grasp/Squeeze/ Pinch	4.Grasp/Clutch/Clasp	All or some of fingers are curled around a stimulus, may include firmer hold or grip.
	5.Poke/Prod/Tickle/Fingerwalk/Push	5.Poke/Prod/Manipulate/ Finger/Scrumble	Involves small repetitive movements, generally in a random fashion. Includes handling or extending finger(s).
	6. Pull/Lift/ Clap/Extension	6. Pull/Lift/Clap/Push	Pulling or pressing of stimulus; striking hands against each other; raising a stimulus higher than its original position.
Remaining (Excluded)		7.Mouthing	Touch through lips, or when infant's hand makes contact with their mouth region.
	7.Shake/Wiggle		Moving part of the infant in short quick motions from side-to-side or up and down.
	8.Other		Any other type of touch that cannot be classified in any of the above categories.

Note. Touch categories pertain to tactile contact via the hands. Shake/Wiggle, Other, and Mouthing were not placed into the global categories of Affectionate/Nurturing or Playful/Stimulating, as they are not shared by the CITS and ITS. The first one to two behaviours of each type of touch are used throughout the text (e.g., Stroke/Caress vs. Stroke/Caress/Rub/Massage/Wipe) to facilitate reporting of results.

Table 2. *Means and standard errors corresponding to the percent durations of mothers' and infants' global touching behaviours across time and context.*

	Floor Context				Lap Context			
Global	Mother		Infant		Mother		Infant	
Type of Touch	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Affectionate/Nurturing								
Time 1	16.66	4.49	73.72	4.49	57.31	4.61	65.11	4.61
Time 2	6.25	4.73	46.61	4.73	51.47	5.41	42.41	5.41
Time 3	15.28	4.32	9.98	4.32	53.04	3.29	23.19	3.29
Time 4	3.39	3.20	12.44	3.20	5.72	4.50	33.85	4.50
Time 5	89.50	1.69	5.19	1.69	72.19	5.25	30.63	5.25
Playful/Stimulating								
Time 1	15.91	3.90	8.97	3.90	21.45	3.45	5.79	3.45
Time 2	8.68	4.08	22.43	4.08	23.32	3.53	10.71	3.53
Time 3	4.86	4.90	62.10	4.90	34.67	4.26	26.33	4.26
Time 4	10.63	4.67	61.09	4.67	31.02	5.63	39.65	5.63
Time 5	5.18	3.76	60.72	3.76	16.78	5.64	46.41	5.64

Table 3. *Means and standard errors corresponding to the percent durations of mothers' and infants' individual touching behaviours across time and context.*

	Floor Context				Lap Context			
Individual	Mother		Infant		Mother		Infant	
Type of Touch	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Static								
Time 1	8.95	3.66	61.41	3.66	37.34	4.27	52.63	4.27
Time 2	4.87	3.94	32.85	3.94	40.09	5.18	34.90	5.18
Time 3	12.97	3.89	5.43	3.89	49.25	2.97	17.78	2.97
Time 4	1.33	2.70	9.09	2.70	3.77	4.51	24.04	4.51
Time 5	.61	.87	3.67	.87	1.85	2.07	22.19	2.07
Stroke/Caress								
Time 1	3.69	1.01	7.35	1.01	8.55	1.63	12.06	1.63
Time 2	.97	1.74	12.29	1.74	5.66	1.53	6.32	1.53
Time 3	1.78	1.20	3.85	1.20	2.96	.71	4.44	.71
Time 4	1.21	.30	.51	.30	1.04	.35	1.66	.35
Time 5	88.52	1.45	.53	1.45	69.73	5.34	.90	5.34
Pat/Tap								
Time 1	4.03	1.76	4.96	1.76	11.43	2.52	.42	2.52
Time 2	.41	.33	1.48	.33	5.71	1.70	1.19	1.70
Time 3	.53	.22	.69	.22	.83	.32	.98	.32
Time 4	.85	.74	2.84	.74	.91	2.03	8.15	2.03
Time 5	.37	.26	.99	.26	.61	1.07	7.54	1.07
Grasp								
Time 1	2.10	1.34	3.70	1.34	3.54	1.11	5.11	1.11
Time 2	1.45	3.94	21.92	3.94	5.17	1.64	8.84	1.64
Time 3	1.08	4.75	61.83	4.75	4.75	3.95	25.14	3.95
Time 4	8.53	4.59	51.10	4.59	23.01	5.03	29.78	5.03
Time 5	3.70	3.54	45.76	3.54	12.13	5.09	38.81	5.09
Pull/Lift								
Time 1	10.63	3.26	1.07	3.26	17.58	2.88	.00	2.88
Time 2	5.10	.67	.05	.67	16.91	3.04	.10	3.04
Time 3	1.75	.51	.22	.51	26.69	1.98	.07	1.98
Time 4	1.20	1.23	6.00	1.23	4.33	1.46	.05	1.46
Time 5	.03	1.32	13.24	1.32	.62	.85	2.25	.85
Poke/Prod								
Time 1	3.18	1.40	.33	1.53	4.20	1.40	.67	.15
Time 2	2.13	.63	1.24	.43	.46	.63	1.76	.43
Time 3	2.03	.74	3.23	.64	.05	.74	1.12	.64
Time 4	.90	.78	3.69	1.51	3.98	.78	9.82	1.51
Time 5	1.45	.54	4.03	1.10	1.72	.54	5.35	1.10

Figure 1. *Percent durations of mothers' and infants' Affectionate/Nurturing and Playful/Stimulating types of touch over time and specifically within the Floor context.*

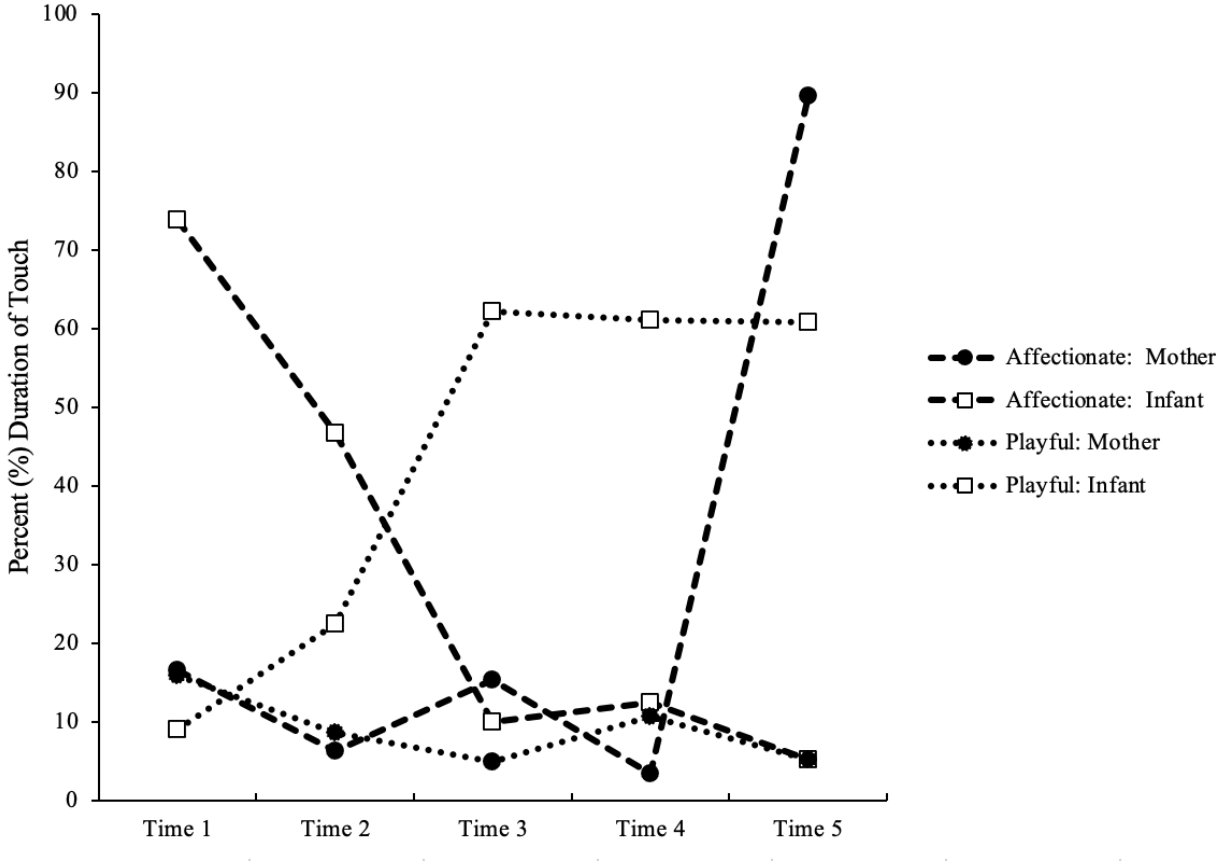
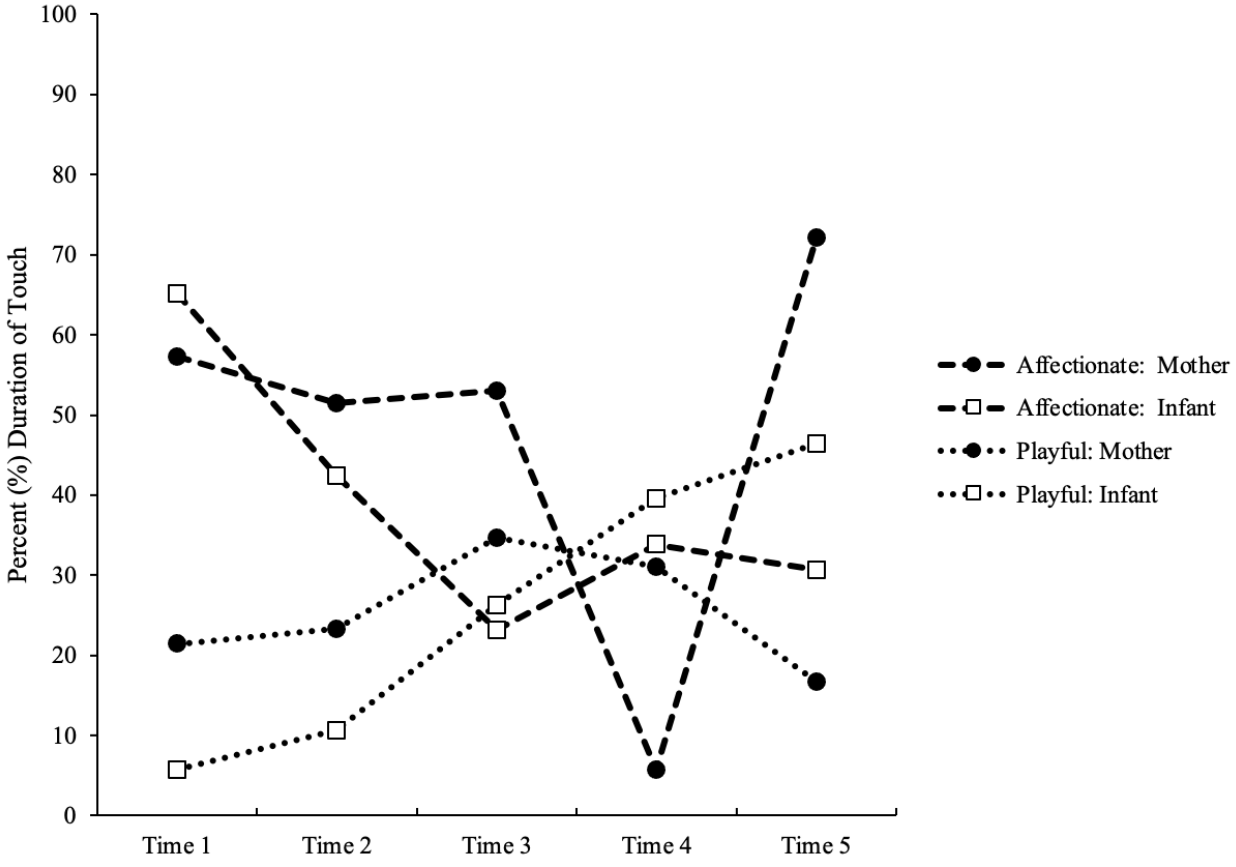


Figure 2. *Percent durations of mothers' and infants' Affectionate/Nurturing and Playful/Stimulating types of touch over time and specifically within the Lap context.*



Chapter 3: Transition Statement Between Study 1 and Study 2

Study 1 investigated mothers' and infants' use of touch, as well as the synchrony of their touching behaviours, within typical interaction contexts and longitudinally across the first 9-months of life. Results from this study revealed that mothers' and infants' individual touch patterns, and the synchrony of mother-infant touch, varied according to the context of the dyadic interaction, the age of the infant, and the specific type of touch examined. Initially, mother-infant dyads displayed more matching in their touching behaviours, especially those that are rudimentary in nature (e.g., static touch, stroking). However, as infants aged, dyads transitioned to more complex forms of tactile coordination involving the use of complementary types of touch (e.g., grasp, poke, pull). Findings uniquely revealed that tactile synchrony emerges as early as the first month of life, suggesting that this form of synchrony may be the first to develop and may be the basis for other forms of behavioural synchrony (i.e., visual, vocal, or multi-modal synchrony). As such, Study 1 underscored the value of detailed, bidirectional investigations of touch and meaningfully added to our understanding about the development of touch.

Study 2 built on these findings and further explored the development of touch by examining the scope and pervasiveness of newborns' earliest displays of touch during their very first naturalistic interaction with their parents. Study 2 investigated whether mother-infant tactile synchrony may emerge immediately after birth, and thus sooner than 1-month postpartum (as demonstrated in Study 1). To further our knowledge about the progression of tactile synchrony, the coordination of maternal and infant touch across perturbed mother-infant interactions was examined longitudinally, from the immediate postpartum period to 3-months postpartum. In contrast to the normative and playful interactions examined in Study 1, families in Study 2 were observed naturalistically in the hospital delivery room following the physiological stress of labor, and then in a laboratory setting, whereby dyads interacted during the Still-Face procedure (SF;

Tronick et al., 1978) and were exposed to a social stressor (i.e., maternal emotional unavailability). Our previous investigation of this sample unveiled the parallel nature of these interactive contexts (post-birth, post-SF) and demonstrated the predictive quality of maternal touch (Mercuri et al., 2019). The present study was designed to expand on this prior research and the limitations of the extant literature by exploring whether newborn touch also has predictive properties and is associated with the touching behaviours of these same infants 3-months later.

Given that Study 1 focused solely on mother-infant touch, and touch does not occur in isolation (Mantis & Stack, 2018), Study 2 was also designed to further advance our knowledge of the tactile modality by exploring the interplay of mothers', fathers', and infants' individual touching behaviours and other more global behaviours. That is, newborns' displays of crying and fussing, mothers' displays of maternal pain, and their first experiences of breastfeeding were each measured and examined in relation to touch. These global behaviours were selected as they are characteristic of the immediate postpartum period and further define it as a unique naturalistic context. By including behaviours that were displayed by fathers, behaviours tied to other communicative modalities, and those linked to mothers' and infants' physiological support systems, Study 2 allowed for a more complete understanding of touch as a fundamental channel of communication and offers rare insight into its inherent functions during parents' and infants' earliest social exchanges.

Chapter 4: Dissertation Study 2

From the First Touch: Newborns' and parents' touching behaviours during triadic and dyadic interactions immediately after birth and at 3-months postpartum

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Manuscript submitted to *Infancy* and under review:

Mercuri M., Stack D.M., Trojan S., Giusti L., Morandi F., Mantis, I., & Montirosso, R. (Under review). From the First Touch: Newborns' and parents' touching behaviours during triadic and dyadic interactions immediately after birth and at 3-months postpartum. *Infancy.*

Acknowledgements. This study was partially funded by the Italian Health Ministry, provided to Scientific Institute, IRCCS Eugenio Medea (Ricerca Corrente 2011: Basi neurobiologiche dell'interazione precoce madre-bambino: studio clinico, neurochimico, neurofisiologico e di neuroi- maging funzionale). The authors gratefully acknowledge financial support from le Fonds Québéçois de la recherche sur la société et la culture (FRQ-SC) and Social Sciences and Humanities Research Council of Canada (SSHRC) for grants awarded to Dale M. Stack (and co-investigators) and SSHRC, FRQ-SC, and Concordia University for M.A. and doctoral level fellowships and support awarded to Marisa Mercuri. The authors gratefully acknowledge the midwives, nursing and clinician staff from the Obstetrics and Gynecology Unit of the Sacra Famiglia Hospital of Erba (Como), Italy. Special thanks to Dr. Alberto Zanini, Director of the Obstetrics and Gynecology Unit of the Sacra Famiglia Hospital of Erba (Como), Italy. The authors would like to thank members of Dr. Stack's Infant and Child Studies Laboratory at Concordia University, including Kimberly Burnside and Joelle Bélisle-Cuillerier for their aid with data preparation, and Gabrielle Schmitt for assistance with the development and application of behavioural observational coding systems. Additionally, the authors would like to thank Dr. Montirosso's team at the 0-3 Center for the at-Risk Infant, Scientific Institute IRCCS, for their valuable contributions. Finally, the authors would like to express their gratitude to the families that participated in this study.

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Abstract

Touch is the first sense to develop and is experienced in the womb, equipping the neonate to engage and communicate with their new world and a vital means through which the sensitive transition from fetal to neonatal life is facilitated. Newborns' touching behaviours were investigated immediately after birth, during their very first naturalistic interaction with their parents and 3-months later, during the Still-Face (SF) procedure. Mother-infant tactile synchrony was also examined across time and context.

Findings revealed that newborn infants spent the large majority of the first hour after birth employing touch (at significantly higher rates than their mothers and fathers) and were especially reliant on rudimentary types of touch such as static touch, mouthing, suckling, flexing, and fisting. Newborn total touch immediately after birth positively predicted infant total touch after, but not before, the SF 3-months later, supporting our previous findings on maternal touch and further revealing the parallel nature of these interactive contexts (post-birth, post-SF). Mothers and infants demonstrated a significant degree of temporal coordination in terms of their touching behaviours; increases in maternal touch were associated with decreases in infant touch, indicating an inverse pattern of tactile synchrony from the immediate postpartum period to the reunion period of the SF procedure 3-months later. This pattern of mother-infant touch synchrony may reflect a reciprocal, turn-taking dynamic produced by mothers' attempts to soothe and regulate their infants following periods of stress (physiological stress following birth, and social stress following SF).

To our knowledge, this is the first study to investigate the full range of newborns' earliest naturalistic and interactive displays of touch, the first to reveal the predictive quality of newborn touch across time and context, and the first to examine the synchronous patterns of maternal and infant touch from birth and longitudinally. Our findings unveil newborns' innate capacity to use

touch as a means of interacting with their parents and uniquely contribute to our understanding about the early development of touch and its integration in social interactions.

Introduction

The transition from womb to world is the most critical and significant life event, as it is the very beginning of life itself (Ferber & Makhoul, 2004; van Manen, 2018). In this "golden hour," the first hour immediately following birth and delivery, the neonate undergoes vast environmental and physiological changes (Castrodale et al., 2014; Phillips, 2013; Pouraboli et al., 2018; Sharma, 2017; VanWoudenberg et al. 2012). Amid these profound adaptations, there is at least one element of continuity for the neonate – *touch.* That is, tactile stimulation is experienced as early as 6-weeks gestation and onward within the womb, during birth, immediately following delivery, and throughout the neonatal period (Gallace & Spence, 2016; Stack, 2010; Mercuri et al., 2019). As the somesthetic system is the very first of all sensory systems to develop, the newborn infant enters the world with the ability to not only perceive and respond to touch, but to utilize touch themselves (Cascio et al., 2019; Montagu, 1971, 1986). Touch therefore equips the neonate to engage and communicate with their new world and is a vital means through which the sensitive transition from fetal to neonatal life is facilitated (Castiello et al., 2010; Ferber & Makhoul, 2004; Hata, 2016).

Touch is also central to another substantial transition occurring at this time: mothers' and fathers' transition into parenthood (Chen et al., 2017; Høifødt et al., 2020; VanWoudenberg et al. 2012). The couples' life is forever transformed following the birth of their child (Mckenzie & Carter, 2013). The first hour after birth signifies an extraordinary event during which mothers and fathers formally begin their lifelong journey as parents and are now afforded their very first opportunity to feel and touch their infant (Wiberg, 1990). Although they have already begun to form an emotional bond throughout pregnancy, this bond becomes even more powerful with parents' newfound ability to directly interact with their child (Carcozza & Leong, 2021; Phillips, 2013; Smorti et al., 2020). Touch is likewise a critical channel of communication for mothers

and fathers, enabling them to demonstrate their love and affection (Botero, 2018), and to implement necessary caregiving behaviours such as feeding, bathing, and soothing (Egmose et al., 2018; Jean & Stack, 2009; Montirosso & McGlone, 2020; Underdown et al., 2010). As such, the tactile sense equips parents to attend and respond to the various needs of their infants and thus facilitates their own sensitive transition to a new life (Mantis et al., 2019; Mckenzie & Carter, 2013).

Benefits of Physical Contact between Parents and Newborns

The remarkable role of touch regarding the momentous transitions experienced by neonates *and* parents immediately following birth is further underscored by research on skin-to-skin contact (i.e., Kangaroo care), a caregiving practice involving the newborn infant's naked body being placed directly onto the parent's bare chest (Widström et al., 2020). This form of contact is recommended world-wide and now commonly implemented as part of hospital care routines in the proximate moments following labor and delivery (Phillips, 2013). It is especially useful for the mother-infant dyad, as it naturally reduces the physiological stress experienced by the mother due to giving birth, as well as the physiological stress experienced by the newborn infant due to being born (Bystrova et al., 2003; Csaszar-Nagy & Bókkon, 2018). Specifically, skin-to-skin contact at this time is associated with reduced maternal stress, limited bleeding, earlier expulsion of the placenta, and increased breastfeeding self-efficacy (Abdelmenem et al., 2019; Widström et al., 2019). This same form of contact has been found to benefit the infant as it reduces crying, improves sleeping, and encourages breastfeeding behaviours (Erlandsson et al, 2007; Walters et al., 2007). Moreover, among full-term as well as preterm and at-risk newborns, skin-to-skin contact regulates cortisol, body temperature, blood glucose levels, and respiratory functioning (Bramsom et al., 2010; Montirosso & Provenzi, 2015; Neu et al., 2008). In these ways, physical contact eases the progression of the immediate postpartum period, as a whole and

in relation to other more global behaviours characteristic of this period, notably, infant crying, maternal pain, and breastfeeding (Barnett, 2005; Feldman et al., 2003; Widström et al., 2020).

Gaps in the Extant Touch Literature

Despite the significant transitions that occur within the "golden hour," and the substantial evidence indicating the centrality of tactile contact during parents' and infants' earliest encounter, very little is known about how touch is used at this time and how touching behaviours may vary according to the aforementioned behaviours that further characterize it (e.g., infant crying, maternal pain, breastfeeding). The tactile modality and the immediate postpartum period are vastly overlooked as compared to other communicative modalities and interactive contexts, respectively (Botero et al., 2019; Stack & Jean, 2011). The few studies (i.e., de Château, 1976; Klaus et al., 1970; Robin, 1982; Rodholm & Larsson, 1979; Rubin, 1963; Trevathan, 1981) that have considered touching behaviours within this exceptional and naturalistic context of birth have mainly described the sequences or orderly patterns of parents' touch, and not necessarily the specific kinds and amounts of touch. Early studies of this kind were also limited given that they primarily investigated mothers', and not fathers', touch and with examinations of separate dyadic (i.e., mother-infant *or* father-infant), rather than triadic (i.e., mother-father-infant), interactions. In light of research indicating that parents shape one another's behaviour (Feldman et al., 2003), there is a need for concurrent observations of both maternal and paternal touch starting from their earliest interaction with their newborn infant.

Our previous study (see Mercuri et al., 2019) was the first to thoroughly investigate mothers' and fathers' touching behaviours *simultaneously* during their first naturalistic *triadic* interaction in the initial moments to an hour after birth. Findings revealed that parents' use of touch at this time extends far beyond skin-to-skin contact as mothers and fathers were found to display a range of touching behaviours directed toward their newborn infant, including stroking,

caressing, massaging, rubbing, holding, and kissing, in addition to static touch (i.e., touch without movement). Parents did not differ in the quality (i.e., types of touch displayed), but did differ in terms of the quantity, of their touch as mothers displayed significantly higher amounts of these touching behaviours than fathers (Mercuri et al., 2019). While our previous work represents a notable contribution to our understanding about touch in the immediate postpartum period, the ways in which parental touching behaviours relate to factors that help shape this unique context remain critical to address and explore (Pouraboli et al., 2018). Specifically, it is not yet clear how parents' naturalistic touching behaviours vary in accordance with infant crying, displays of maternal pain, and breastfeeding, which are behaviours known to occur throughout the immediate postpartum period and are typically facilitated by the tactile modality (Erlandsson et al., 2007; Widström et al., 2019). An investigation of this nature would permit us to attribute more meaning to the varying touching behaviours displayed in this context, elucidating the communicative messages and functions that underlie the tactile modality at birth.

Newborn Touch in the First Hour

An area of research that is even more vital to our understanding of touch but has been greatly understudied is *newborns'* use of touch in their first moments of life and throughout their very first encounter with their mothers and fathers. It is surprising that such a gap remains in the literature given that neonates are highly alert in the first hour after birth and emerge from the womb ready to interact through touch (Bramson et al., 2010; Crucianelli & Filippetti, 2020). Their propensity to use the tactile modality as a means of social engagement from the very moment they are born is underscored by advances in four-dimensional ultrasound technology demonstrating the fetus' ability to perform tactile motions with coordination and intention (Botero, 2018; Hata, 2016; Reissland & Austen, 2018). For example, Castiello and colleagues (2010) revealed that twin fetuses use touch to interact with one another within the womb and

demonstrate movements that are not merely reflexive but are goal-directed and purposely targeted toward their co-twin, the uterine wall, or themselves. The intentionality of fetal touch is further highlighted by findings indicating that, especially within the third trimester, fetuses increase left-handed self-touch in relation to increases in maternal stress (Reissland et al., 2015), and selectively increase self-touch behaviours in response to their mothers providing external stimulation by touching her abdomen (Marx & Nagy, 2015). The tactile movements and behavioural patterns observed in the fetal period can also be observed neonatally (Hata, 2016). Hence, infants are born with a preparedness to use touch as a channel of social responsiveness and engagement, and as a way of self-regulating during periods of stress.

Nonetheless, our knowledge about the early development of infant touch, especially starting from the first moments after birth, is extremely scant (DiMercurio et al., 2018). Much like the limited studies on parental tactile behaviours in the immediate postpartum period, the scarce research on newborn touch at this time has focused on orderly patterns and sequences (Widström et al., 1987; Wiberg, 1990). For instance, Matthiesen et al. (2001) reported that right after birth, the newborn infant's hand is open and relaxed. A few minutes later, the infant is observed to display massage-like movements on the mother's breast, followed by their first hand-to-mouth movement (Matthiesen et al., 2001). Congruently, a more recent study by Widström et al., (2011) indicated that infants displayed a short period of relaxation without any body movements when placed on their mother's chest shortly after birth, and later made hand-mouth-breast movements. Such descriptions imply that neonatal touch is minimal and simplistic, revealing little to no information about the specific types of touching behaviours displayed by infants, nor the scope and pervasiveness of these behaviours, from the moment they are born and throughout the first hour of life. These studies therefore appear to overlook the dynamic and

multidimensional nature of the tactile modality (Hertenstein, 2002; Stack, 2010; Stack & Jean, 2011), and do not address the most fundamental aspects of human touch.

Development of Infant Touch: From the First Hour Onward

Given that much remains unexplored to date, it follows that the progression of infant touch from birth and across the first few months of life – a highly sensitive period of human development whereby many behavioural changes are expected to occur – has also been largely overlooked (Pouraboli et al., 2018). The development of infant touch, and touch in general, cannot be truly understood without investigations of this nature. Longitudinal studies of infant touch are certainly lacking within the literature despite their ability to answer rudimentary questions regarding the evolution of humans' most primary and crucial means of communication (Field, 2019; Crucianelli & Filippetti, 2020). To our knowledge, Thomas et al. (2015) conducted one of the only studies of this kind; they described the spontaneous self-touching hand movements displayed by infants while lying on their back or sitting in a baby seat, starting from the first few days across the first 6-months of life. DiMercurio et al. (2018) also investigated spontaneous touch activity of infants every week while placed in the supine position, starting from 3-weeks to 2-months of age. It is important to note that each of these two studies focused on developmental changes pertaining to the *location* of infants' tactile movements; the former indicated that infants initially touch their head and torso more frequently and increasingly touch their legs as they age (Thomas et al., 2015), whereas the latter demonstrated that infants spend 50% of the time moving their hands from one location to the next (e.g., across body or floor) throughout the first 2-months of life (DiMercurio et al., 2018). Similar to the studies discussed previously (i.e., Matthiesen et al., 2001; Widström et al., 2011), these investigations fail to describe the scope and pervasiveness of infant touching behaviours. Although these studies support the initiative toward longitudinal investigations of infant touch shortly after birth, they

do not examine the progression of infant touch *immediately* after birth, and do not consider touch within the context of parent-infant interactions. Consequently, our knowledge about the early development of touch in relation to one of its most primary functions – its social and communicative function – is largely incomplete (Hertenstein, 2002; Field, 2019; Nguyen et al., 2021).

Still-Face Procedure

Indeed, parent-infant interactions are necessary contexts for studying the development of touch. In addition to the immediate postpartum period (an extraordinary naturalistic context), experimental parent-infant exchanges have proven to be informative contexts for the study of touch (Mantis et al., 2019; Mantis & Stack, 2018). The classic Still-Face procedure (SF; Tronick et al., 1978) is one notable example of this kind of context that has yielded meaningful findings about the tactile modality and mother-infant dyads. This procedure consists of three structured face-to-face interactions; following and preceding two periods of normative social exchange (i.e., the normal and reunion periods), mothers are asked to maintain a still or neutral facial expression while looking at their infant and while abstaining from any other form of communication including touch (i.e., the SF period). Due to the violation of social norms and expectations, and the apparent emotional unavailability of the mother, the SF period is a perturbed interaction that produces a mild form of social stress (Lowe et al., 2016; Stack & Muir, 1992). In turn, infants have been found to display a signature SF effect, characterized by increased negative affect and decreased smiling and gazing toward the mother (Lamb et al., 1987; Muir & Lee, 2003). The limited number of studies which have utilized this experimental paradigm to explore changes in touch have found that infants engage in more soothing, regulatory, and exploratory touching behaviours during the SF period as compared to the normal and reunion periods (Moszkowski & Stack, 2007; Moszkowski et al., 2009). A study that implemented a modified version of the

procedure by directing mothers to use only touch during the SF period interestingly found that maternal touch significantly diminished infants' signature SF effect (Stack & Muir, 1990). Findings such as these underscore the value of the SF procedure as a tool to measure behavioural changes in mother-infant interactions, and by extension, the comforting and soothing functions of touch (Stack, 2010).

Though most research on the SF procedure has been cross-sectional, it has been more recently integrated into longitudinal designs exploring the development of infant and maternal behaviours. Studies by Bigelow and Power (2012) and Owusu-Ansah et al. (2019) illustrate this use for the SF procedure by examining whether variations in skin-to-skin contact across the first week to a month of life produced differences in infants' responses to the SF up until 3-months later. One noteworthy finding was that infants who received regular skin-to-skin contact across this period were more responsive and appeared more eager to re-engage with their mothers (as demonstrated by increased non-distress vocalizations) during the SF period at 3-months of age (Bigelow & Power, 2012). Our prior study (i.e., Mercuri et al. 2019) further illustrated the contributions of the SF procedure to longitudinal examinations of touch across the first 3-months of life. We uniquely revealed that more maternal touch displayed immediately after the naturalistic perturbation of labor predicted more soothing and nurturing maternal touch 3-months later, subsequent to the experimental perturbation of the SF period. Findings unveiled the parallel nature of these two contexts representing the physiological stress of labor and the social stress of the SF, the predictive quality of maternal touch, and the corresponding centrality of affectionate touching behaviours (Mercuri et al., 2019). Since infant touching behaviours are likewise tied to contextual factors (Hertenstein et al., 2006), and little is known about how infant touch varies from post-labor to post-SF, a longitudinal investigation of the potential predictive quality of newborn touch is warranted.

Importantly and taking even further steps, the longitudinal link across these post-perturbation contexts has yet to be examined within bidirectional or simultaneous investigations of touch, which aim to capture how infants use touch in direct relation to the touching behaviours displayed by their mothers – their most frequent interaction partners (Biringen et al., 2014). According to the dynamic systems perspective, mothers and their infants form a mutually regulated system in which they are sensitive and responsive to the changes displayed by one another (Beebe et al., 2016; Field, 2014; Fogel, 2009). Transactional models of development similarly posit that the behavioural changes of a parent will likely have an influence on the infant's behaviour, and vice versa (Pesonen et al., 2008; Sameroff, 2010). Research stemming from these frameworks and which accounts for concurrent and reciprocal changes has revealed that mother-infant dyads produce synchronous patterns during their interactions (Harder et al., 2015; Field, 2014; Mastergeorge et al., 2014; Pettit & Arsiwalla, 2008).

Synchrony

Behavioural synchrony, in particular, is recognized as a key feature of mother-infant interactions and highlights the dynamic interplay that exists between maternal and infant behaviours (Feldman, 2017; Leclère et al., 2014; Nguyen et al., 2021). It is distinguished from behavioural mimicry or matching, which is when both members of a dyad display an identical pattern of behaviour (Mayo & Gordon, 2020). Instead, behavioural synchrony is defined as the degree of temporal coordination between infants' and mothers' behaviours over time (Busuito et al., 2019; Hsu & Fogel, 2001). This process may thus be conceptualized as the rhythmic pattern that emerges within the dyad (Hoehl et al., 2021). The importance of synchrony during early mother-infant interactions is emphasized by research demonstrating the positive implications it has for the formation of a secure attachment (Isabella & Belsky, 1991), mother-infant bonding

(Feldman, 2017), and long-term childhood outcomes tied to their psychological and emotional well-being (Ambrose & Menna, 2013).

In line with the research reviewed above, touch represents the most understudied component of behavioural synchrony relative to the visual and vocal modalities (Harder et al., 2015; Field, 2010; Lavelli & Fogel, 2005). However, touch is arguably the most critical sensory modality to the study of interpersonal synchrony (Crucianelli & Filippetti, 2020). Touch is rather unique due to the fact that it is the only sense that is inherently mutual, shared, and multisensory (Ciaunica & Fotopoulou, 2017). Because touch requires close physical contact and proximity, one cannot touch someone else without also experiencing touch themselves, and without automatically receiving feedback from their other senses such as smell and vision (Crucianelli & Filippetti, 2020; Merleau-Ponty, 1964; Montirosso & McGlone, 2021). Affectionate touch (i.e., affective; defined as non-noxious light stroking, pressure, and holding; Hertenstein, 2002), especially, has been found to facilitate behavioural as well as neural and physiological forms of synchrony (Carozza & Leong, 2021; Goldstein et al., 2017; Hoehl et al., 2021). Newborns notably demonstrate a preference for this type of touch, as well as for synchronous tactile stimulation, in the first few hours of life (Filippetti et al., 2013; Montirosso & McGlone, 2021). Moreover, affectionate touch between infants and their mothers is regarded as the foundation of infants' ability to regulate themselves in terms of both their interoceptive and exteroceptive states (Crucianelli & Filippetti, 2020; Busuito et al., 2019). Tactile synchrony may therefore serve as an important mechanism through which the mother-infant dyad adapts to physiological, emotional, and environmental changes, and through which other forms of synchrony emerge. Taken together, research highlights the need for examining the development of mother-infant synchrony via touch under conditions that foster increased co-regulation, particularly during a

sensitive period of infant development and within contexts that are characterized by pronounced transitions.

The Present Study

The current study was formulated to address fundamental questions about touch as well as to obtain a more complete, comprehensive understanding about its development and role in early parent-infant interactions. The following were the specific objectives of this investigation: 1) to describe the full range of newborns' touching behaviours just minutes after birth and delivery and how these relate to parental touching behaviours and other more general behaviours which characterize the immediate postpartum period (i.e., infant crying, breastfeeding, and maternal pain), 2) to examine how infant touching behaviours displayed immediately after birth relate to their touch 3-months later and throughout the SF procedure, and 3) to investigate mother-infant tactile synchrony across these same time points and contexts. The present study builds on previous research using this sample by examining the three innovative objectives in the two interactive contexts that each follow periods of naturalistic and experimental perturbations (i.e., post-labor, post-SF; Mercuri et al., 2019).

Method

Participants

Primiparous women referred to the prenatal care program implemented at the Fatebenefratelli Sacra Famiglia Hospital, Erba (Como), Italy were recruited during the last trimester of pregnancy. To participate, mothers must not have been single parents, under the age of 18 years, or using recreational drugs. Mothers diagnosed with emotional disorders, or undergoing an at-risk pregnancy, were also excluded from the current study. Thirty-one mothers and fathers agreed to participate in the current study with their infants. Due to technical difficulties regarding the video recording of the parent-infant interactions, 9 families were

excluded. The final sample thus included 22 mothers, fathers, and infants. Mothers' ages ranged from 22 to 42 years (M = 33.43, SD = 5.63), whereas fathers' ages ranged from 28 to 46 years (M = 36.78, SD = 5.02). All couples were having their first child together and were either cohabitating or married. During the first time point (Time 1), infants were only minutes old, having just been born. All infants were full-term and delivered vaginally and without analgesia. These were all medically judged to be low-risk deliveries. During the second time point (Time 2), infants were approximately 3-months-old; their ages ranged from 2.9 to 3.4 months, with one infant who was 4.6 months (M = 3.16, SD = .35). This infant, despite being slightly older, was included in the sample as no meaningful differences from the remainder of the sample were observed and data was adjusted for outliers (see Data Integrity section below). Of the 22 infants (no attrition), 13 were male and 9 were female. An index of family socio-economic status was obtained according to Hollingshead's (Hollingshead, 1978) classification (Hollingshead, 1975); lower scores reflect lower SES. On this index, scores ranged from 30 to 90 (M = 54.09, SD = 16.81), indicating that families were of middle to upper social class. Participants were all of Italian nationality.

Measures

Demographic Questionnaire. This self-report demographic questionnaire consisted of questions concerning mothers' and fathers' ages, occupations, and education, and families' socioeconomic statuses.

Apparatus

Using a hand-held video camera, the Neonatologist (third in the list of authors of the present paper) recorded each interaction period of the procedure at Time 1. For Time 2, the camera was fixed on a tripod. Videotapes were later digitized and transferred onto a computer and DVDs. The video records were then reviewed for behavioural coding using the software

system, Mangold INTERACT. Mangold is a professional software system for behavioural research that allows for the live second-by-second qualitative and quantitative analysis of multimedia data.

Procedure

This study was conducted in accordance with the ethical standards of the American Psychological Association, and after approval by institutional ethics review boards at the Sacra Famiglia Hospital of Erba and the Scientific Institute, IRCCS Eugenio Medea. Following ethics review and approval, mothers and fathers provided their informed consent (see Appendix B for consent form). They then (i.e., during the prenatal period) completed various questionnaire measures, including the demographic questionnaire. Minutes after labor and delivery, infants were placed on their mother's chest and the Neonatologist began video recording this very first interaction among newborn infants and their mothers and fathers. No instructions were given to the infants' parents; parents interacted with their infants naturally and as they wanted. Video recordings of this very first interaction (Time 1) lasted approximately 45-minutes. All deliveries took place at the Fatebenefratelli Sacra Famiglia Hospital, Erba (Como), Italy.

Approximately three months later (Time 2), these same mothers and their infants participated in the Still-Face procedure (SF; Tronick et al., 1978). Mothers and their infants completed this procedure at the 0-3 Centre for the At-Risk Infant of the Scientific Institute (IRCCS Eugenio Medea) in Bosisio Parini (Lecco), Italy. Following informed consent, mothers and their infants were seated comfortably in a room at the research laboratory while being video recorded (consent given) during three face-to-face interaction periods. Infants were securely fastened in a car seat, which was placed on a table facing their mothers. Mothers were seated directly in front of their infants and at eye-level. The first interaction period, the normal period, entailed a normal interaction in which mothers were instructed to play with their infants as they

normally would, including visual, vocal, and tactile stimulation. The second interaction period, the SF period, involved mothers looking at their infants using a still, expressionless, neutral, facial expression. During this period, mothers were also asked to abstain from smiling, talking, or touching their infants in order to appear emotionally neutral and, were thus unavailable to their infants, despite being physically present. The final interaction period, the reunion period, involved another interaction in which mothers were again instructed to play with their infants as they normally would, including any form of stimulation. Each interaction period lasted two minutes. The experimenter was in an adjacent room behind a one-way mirror monitoring the video recording and produced a knocking sound to signal the end of each interaction period. Mothers were informed that they were free to discontinue the sessions at any time if desired.

Observational Coding

Videotapes were reviewed second-by-second and coded for touching using reliable and systematic coding systems. Specifically, mothers' and fathers' touching behaviours were coded using the Caregiver-Infant Touch Scale (CITS; Jean et al., 2009; Stack, 2010; Stack et al., 1996), as well as an adapted version of the CITS, the Caregiver-Infant Touch Scale – Adapted (CITS-Adapted; Mercuri et al., 2019). Additionally, infants' touching behaviours were coded using the Infant Touch Scale (ITS; Moszkowski & Stack, 2007) and an adapted version of the ITS, the Infant Touch Scale-Adapted (ITS-Adapted; Mercuri et al., 2020b). The CITS and ITS measure qualitative and quantitative changes in tactile stimulation produced by caregivers and their infants during early interactions. The CITS-Adapted and ITS-Adapted were based on the original aforementioned measures but were designed to capture caregivers' and newborns' touching behaviours during the immediate postpartum period. Refer to Table 1 for a list of the categories and brief descriptions corresponding to each of these touch-based coding systems. Lastly, the Behaviours in the Immediate Postpartum Period Scale (BIPPS; Mercuri et al., 2020a) was used

to code global behaviours characteristic of the first hour after birth and delivery and consisted of three general categories: (1) infant crying/fussing (indicated by negatively toned vocalizations, grimacing, or frowning), (2) breastfeeding (includes mother orienting infant toward breast, latching attempts, as well as uninterrupted moments of breastfeeding), (3) visible displays of maternal pain (entails negatively toned vocalizations including moaning, yelling, and crying, verbiage such as "ow," negative facial expressions such as grimacing, frowning, and tightening of facial muscles, and gestures such as hand covering face or mouth; displays of maternal pain attributed to physical effects of labor and delivery, corresponding difficulty moving positions on hospital bed, and medical procedures following episiotomy/perineotomy).

Coders were first trained on the coding systems to reach a high level of reliability before formal coding commenced. When discrepancies between raters occurred during this training period, coders reviewed the corresponding portion of the video second-by-second, discussed and deliberated the appropriate code for the particular segment on the video, and subsequently re-coded that portion of the video with the mutually agreed upon category. Inter-rater reliability was subsequently conducted between coders (one of the coders was blind to the hypotheses of the study) and determined using kappa coefficients for 30% of the sample. A high inter-rater reliability between coders was determined for each coding system overall, and for the individual categories respective of each coding system (k = .70 to .93).

Data Preparation

For a portion of the analyses, individual touching behaviours were aggregated into a composite touch variable, representing infants' and parents' total or overall touch. In line with previous investigations of touch (Mantis et al., 2019; Mercuri et al., 2009; Moszkowski & Stack,

2007; Moszkowski et al., 2009), infant touching behaviors during the SF[1] procedure were also classified as either affectionate or playful touch. Affectionate touch is characterized by lower paced contact behaviours and includes the following individual types of touch: static, stroke/caress/rub/wipe, pat/tap. Playful touch involves more engaging and effortful contact behaviours and includes the following individual types of touch: grasp/clutch/clasp, poke/prod/manipulate/finger/scrumble, pull/lift/clap/push. Previous investigations utilizing these categorizations of affectionate and playful types of touch have yielded meaningful findings (i.e., Mantis et al., 2019; Moszkowski & Stack, 2007; Moszkowski et al., 2009).

Percent durations for each type of touch were used as dependent variables for each of the analyses to control for any minimal differences in the length of the interaction periods at each interaction time point (Herrera et al., 2004). Percent duration refers to the percentage of time over the length of the interaction period for each dyad that was allocated to a specific type of touch. It was calculated by dividing the raw duration of a specific touch by the length of the corresponding interaction period (and multiplying by 100). Percent durations were likewise used for infant crying/fussing, breastfeeding, and displays of maternal pain, representing the percentage of time allocated to each of these behaviours in the immediate postpartum period.

Statistical Analyses

A series of analysis of variance (ANOVA) were conducted to determine differences between newborns, mothers, and fathers on the percent duration of their total touch (one-way between-groups ANOVA; Objective 1), and to determine differences in the percent durations of infants' affectionate and playful touch across periods of the SF procedure (one-way repeated measures ANOVA for each type; Objective 2). This statistical approach is consistent with previous studies within the literature assessing maternal and infant touch, including but not

1 Infant touching behaviours coded during the SF period were solely self-touch as, due to the nature of this interaction and procedure, infants were unable to touch their mothers at this time.

limited to those also utilizing the SF procedure (e.g., DiMercurio et al., 2018; Granat et al., 2017; Feldman et al., 2010; Field et al., 2007; Jean et al., 2009, Mantis et al., 2019; Mantis & Stack, 2018; Mercuri et al., 2019).

Pearson correlations were conducted to examine associations between the touching behaviours of newborns, mothers, and fathers, as well as more global behaviours characteristic of the immediate postpartum period: infant crying, breastfeeding, and demonstrations of maternal pain (Objective 1). Moreover, in line with previous investigations of this sample (i.e., Mercuri et al., 2019), linear regression analysis was used to determine whether newborn touching behaviors displayed immediately after birth (Time 1) were predictive of infant touching behaviors displayed 3-months postpartum (Time 2; Objective 2).

Multilevel modeling (MLM) procedures were used to analyze dyadic associations in mother and infant touching behaviours from Time 1 to Time 2 (immediate postpartum period to SF procedure 3-months-postpartum; Objective 3; Creaven et al., 2014). According to Davis and colleagues (2018), MLM is the most frequently implemented statistical approach for examining synchrony within parent-child dyads. MLM procedures allow for *dynamic* changes between parents and children to be examined (Davis et al., 2018). Specifically, correlated slopes analyses are used to determine *trend synchrony*, or the degree to which dyad members follow a similar pattern of change over time (Helm et al., 2018). Slopes representing individuals' patterns of change across repeated measures are calculated and are then correlated across dyads; the estimates (i.e., correlation coefficient) produced represent the degree to which partners within dyads share similar patterns of change (Helm et al., 2018) and how coordinated (and not necessarily matched) the dyad's behavioural states are across time (Moore & Calkin, 2004). These analyses have been commonly applied to assess physiological synchrony among parent-child dyads (Bell, 2020), but to our knowledge, have yet to be extended to tactile synchrony. As

such, correlated slopes analyses were implemented in the present study to examine whether changes in maternal total touching behaviours were associated with changes in infant total touching behaviours across time, thereby providing an estimate of mother-infant synchrony for the tactile modality.

Across analyses, results were considered statistically significant at a critical alpha level of .05 and partial eta squared (η_p^2) was reported as a measure of effect size.

Results

Data Integrity

Data were screened for integrity and to ensure that the assumptions of each set of analyses were met. The data cleaning process involved checking for outliers, or scores more than 3 standard deviations away from the mean. Standardized scores were used to identify outliers. Outliers were retained and adjusted by changing their values to the next highest score (Kline, 2009; Tabachnick & Fidell, 2001). ANOVAs, Pearson correlations, and linear regressions were conducted using the Statistical Package for Social Sciences (SPSS, version 26.0) and MLMs were conducted using Mplus (version 8.4).

Objective 1: newborns', mothers', and fathers' specific touching behaviours and general characteristic behaviours in the immediate postpartum period

Descriptive statistics were used to examine newborns' very first displays of touch during their very first interaction with their mothers and fathers, occurring just moments after birth and delivery. Newborns displayed Static touch for the longest percentage of time in the immediate postpartum period, followed by Mouthing/Suckling, Flexing/Fisting, Grasping/Clasping, and Manipulating/Scrumble. The remaining touch categories (Rub/Wipe,

Tap/Pat, and Other) were seldom displayed by newborns. The means and standard deviations[2] for the percent durations of each individual type of newborn touch are provided in Table 2.

A one-way between-groups ANOVA was conducted to compare newborns and their parents with regard to their touch in the immediate postpartum period. Family member (newborn, mother, or father) was the independent variable and percent duration of total touch was the dependent variable. A statistically significant effect of family member was found on the percent duration of total touch, $F(2, 60) = 131.28$, $p = .000$, $\eta_p^2 = .81$. Bonferroni pairwise comparisons revealed that newborns ($M = 86.84\%$, $SE = 3.69$) spent significantly more time displaying total touch during the immediate postpartum period as compared to both their mothers ($M = 32.06\%$, $SE = 3.69$; $p = .000$) and fathers ($M = 3.59\%$, $SE = 3.69$; $p = .000$). Mothers also displayed total touch for a significantly longer amount of time than fathers ($p = .000$).

Descriptive statistics were used to examine the percentages of time attributed to the global behaviours within the immediate postpartum period and were as follows: Breastfeeding ($M = 22.65\%$, $SD = 22.66$), Newborn Crying/Fussing ($M = 15.18\%$, $SD = 14.56$), and Visible displays of maternal pain ($M = 16.68\%$, $SD = 15.63$). Taken together, these specific behaviours accounted for more than half (54.54%) of the immediate postpartum period captured in the present study.

Pearson correlations were utilized to investigate the interrelation of newborns' touching behaviours, parents' touching behaviours, and characteristic behaviours of the immediate postpartum period. Newborns' displays of Static ($r = .80$, $p = .000$) and Mouthing/Suckling ($r = -.62$, $p = .003$) were significantly correlated with Breastfeeding. With regard to the percent duration of maternal touch behaviours, Holding ($r = -.51$, $p = .017$) and total touch ($r = -.45$, $p = .038$) significantly correlated with Newborn Crying/Fussing. Maternal Stroke/Caress ($r = -.47$, p

2 Descriptive statistics for mothers' and fathers' touching behaviours are reported in Mercuri et al., 2019.

= .030) and total maternal touch (r = -.54, p = .012) significantly correlated with Breastfeeding. Additionally, fathers' displays of Kissing their newborns (r = .51, p = .020) significantly correlated with Breastfeeding. No other newborn, maternal, or paternal touching behaviours correlated with Breastfeeding or Newborn Crying/Fussing, and no variables were correlated with Visible Displays of Maternal Pain (p>.05).

Objective 2: infant touching behaviours from birth to 3-months later and across the SF procedure

Linear regression analysis was used to determine whether infant touch displayed immediately after birth was predictive of infant touch displayed 3-months postpartum. It should be noted that total touch at both time points represents the composite of all touching behaviours displayed by infants; for consistency purposes, however, the Pull/Push/Clap/Lift category was excluded from the composite of total infant touch at Time 2 as it was not a category that overlapped with infant touch at Time 1. Results revealed that the total percentage of infant touch at Time 1 was found to be a significant predictor of the total percentage of infant touch at Time 2 during the reunion period of the SF procedure (β = .486, t = 2.42, p = .025), but not during the normal period (p > .05) or the still-face period (p > .05). As such, more infant touching in the post-perturbation period after birth was associated with more touching during the post-perturbation period at 3-months postpartum.

Two separate one-way repeated measures ANOVAs were conducted to determine differences in infant touch across all three periods of the SF procedure. For both analyses, period (normal, still-face, and reunion) was the independent variable. The percent duration of infants' *affectionate touch* was the dependent variable for the first analysis, whereas the percent duration of infants' *playful touch* was the dependent variable for the second analysis.

Results revealed a statistically significant effect of period on the percent duration of affectionate/nurturing infant touch, $F(2, 40) = 11.31$, $p = .000$, $\eta_p^2 = .361$. Follow-up Bonferroni post-hoc comparisons revealed infants used significantly more affectionate touch during the SF period ($M = 55.00\%$, $SE = 19.67$) as compared to the normal ($M = 33.91\%$, $SE = 12.80$; $p = .001$) and reunion periods ($M = 41.63\%$, $SE = 18.38$, $p = .025$). The normal and reunion periods did not significantly differ ($p = .201$). Results also indicated a statistically significant effect of period on the percent duration of playful touch, $F(2, 40) = 8.88$, $p = .001$, $\eta_p^2 = .308$. Follow-up Bonferroni post-hoc comparisons revealed infants significantly decreased their use of playful touch from the normal ($M = 48.02\%$, $SE = 21.11$) to the SF period ($M = 24.95\%$, $SE = 16.71$; $p = .002$), and significantly increased their use of playful touch from the SF period to the reunion period ($M = 44.38\%$, $SE = 21.30$; $p = .006$). The normal and reunion periods did not differ ($p = 1.00$). Results depicted in Figure 1.

Objective 3: mother-infant tactile synchrony following periods of post-perturbations starting immediately after birth to 3-months postpartum.

Correlated slopes analyses were conducted to determine whether changes in infants' overall touch were associated with changes in mothers' overall touch during post-perturbation interaction periods from birth to 3-months postpartum, allowing for an assessment of strength in the relationship between maternal and infant touch (i.e., synchrony). Results revealed that the rate of change of total maternal touch was associated with total infant touch from the immediate postpartum period to the reunion period of the SF procedure 3-months later ($b = -.67$, $SE = .29$, $p = .023$). Across the post-perturbation periods from Time 1 to Time 2, increases in mothers' overall touch were associated with decreases in infants' overall touch, indicating a strong inverse pattern of synchrony.

Discussion

In the present study, we examined newborns' earliest displays of touch during their very first triadic parent-infant interaction from their first moments to hour of life, and how these related to their mothers' and fathers' touching behaviours, to more deeply understand the development of touch and mother-infant synchrony. To our knowledge, this study was the first to describe the specific types and amounts of touching behaviours displayed by newborns *immediately* after birth and concurrently with mothers' and fathers' touch. Additionally, the present study was the first to examine the predictive quality of newborn touch and took the initial steps toward examining mother-infant tactile synchrony. These contributions deepen our understanding about an important developmental period and the dynamics of touching during critical contexts of interaction. Results from our study capture the naturalistic progression of the immediate postpartum period and elucidate our limited understanding about infants' propensity to use touch during parent-infant interactions from birth and onward. The objectives of the present study were designed to address fundamental gaps in the literature and were founded on previous research highlighting the centrality of touch and synchrony to healthy infant development.

Newborn Touch Immediately After Birth

The first objective of the present study was to describe the full range of newborns' touching behaviours displayed in the immediate moments following birth and delivery. Newborns' earliest displays of touch were examined in relation to the touching behaviours of their mothers and fathers, as well as other global behaviours characteristic of the immediate postpartum period. Findings demonstrated that newborns enter the world readily able to utilize touch. The neonates in our sample spent the large majority of their first-ever social interaction employing touch (at least 86.34%, and possibly more, as the remaining 13.16% of the interaction

could not be coded for touch due to technical issues or lack of visibility of neonates' hands). While newborns displayed a range of tactile behaviours, and not just one or two single tactile behaviours, they appeared to be most reliant on rudimentary types of touch including static touch, mouthing, suckling, flexing, and fisting. As discussed by Reissland and Austen (2018), these forms of touch have been observed prenatally via fetal ultrasound images, and the ability to coordinate hand-mouth touch actions is developed before birth. Newborns in the present study seldom displayed rub/wipe and tap/pat touching behaviours, classified as affectionate (soothing, regulatory) types of touch. Thus, it is suggested that these specific behaviours require more refined coordination and better developed motor skills. Previous research has demonstrated that newborns prefer tactile contact that is soft, warm, and gentle (Brazelton, 1977; McGlone et al., 2017). Static touch entails touch without movement yet is likewise understood as having affectionate and regulatory properties. Therefore, the pervasiveness of static touch during the immediate postpartum period relative to other newborn touching behaviours may reflect newborns' efforts to soothe themselves in light of their physical and developmental limits. As compared to both their mothers and fathers, newborns displayed significantly higher rates of overall (total) touch in the immediate postpartum period. Given that the somaesthetic system is the very first to develop and that touch represents infants' very first means of communication (Field, 2010; 2014; 2019), newborns are understandably more dependent on touch than their parents, who in contrast can readily and effectively communicate using all modalities.

Associations Between Touch, Breastfeeding, Infant Crying, and Maternal Pain

Findings additionally revealed a number of key associations between specific types of newborn and parental touching behaviours and the more global behaviours characteristic of the immediate postpartum period. That is, increases in the percent duration of breastfeeding were associated with increases in newborns' static touch, suggesting that breastfeeding may have been

a calming and soothing activity. Increased breastfeeding was also associated with decreased newborn mouthing and suckling, which is intuitive given that both behaviours are oral-haptic in nature and therefore less likely to occur at once. These findings are consistent with previous research indicating that newborn infants discontinue hand movements during suckling and reinitiate hand movements upon the cessation of suckling (Matthiesen et al., 2001). Furthermore, higher percentages of breastfeeding were associated with higher rates of fathers' kissing of newborns, interestingly also oral-haptic in nature (and perhaps indicative of behavioural matching between fathers and their infants), and lower rates of total maternal touch, including stroking and caressing. As such, breastfeeding may elicit increased displays of affection from fathers, as they may feel increasingly connected to both their newborn infant and partner during this initial feeding experience. Mothers' decreased displays of touch, on the other hand, may be explained by their need to attend and adjust to the novelty and potential physical discomfort of breastfeeding for the first time (Kronborg et al., 2015).

Associations between tactile behaviours were found in relation to infant crying/fussing as well. Specifically, increases in maternal touch, including holding, were correlated with decreases in newborn crying and fussing, underscoring mothers' intrinsic ability to use touch to comfort their newborn infants. Although previous findings support regulatory functions of specific types of maternal touch (e.g., affectionate touch; Crucianelli & Filippetti, 2020; Busuito et al., 2019; Jean & Stack, 2009), our results suggest that general forms of maternal tactile contact may suffice in soothing newborns postnatally. Such findings are in line with literature centered around skin-to-skin contact, indicating that physical contact between mothers and their newborns is associated with reduced newborn crying (Phillips, 2013). Contrarily, parental and newborn touching behaviours were not significantly associated with demonstrations of maternal pain in the immediate postpartum period. These null findings can be taken as evidence that maternal

pain creates a pause in this triadic interaction. From the perspectives of dynamic systems and transactional models of development, it is possible that the maternal availability and responsiveness are hindered during instances of physical pain and lead fathers and newborns to halt their own displays of touch. Previous research noting the link between mothers' experiences of pain and difficulty engaging in parent-child interactions (Mackenzie et al., 2018) provides preliminary support for this notion. However, additional research examining dynamic communication patterns during instances of maternal pain is required to validate our findings. Nonetheless, this set of findings shed light on how touching behaviours vary not only within the immediate postpartum period as a whole, but also in relation to other maternal and infant behaviours that typically occur throughout this momentous occasion.

Infant Touch Across Time and Context

The second objective of this study was to examine whether newborn touching behaviours predicted the touching behaviours of these same infants 3-months later, and how their touch varied across all three periods of the SF procedure. Our previous study with this same sample revealed the predictive quality of nurturing maternal touch and the parallel nature of the post-birth and post-SF perturbations (Mercuri et al., 2019). In the present study, we sought to examine the predictive qualities of *infant* touch. Findings revealed that higher rates of infants' overall touch displayed immediately after birth significantly predicted higher rates of infants' overall touch displayed in the reunion period, and not in the normal and SF periods, 3-months later. These results provide additional evidence for a link between the post-birth and post-SF contexts uniquely revealing the predictive quality of newborn touch and contribute to our understanding about its development.

Concurrent findings pertaining to infant touch across the SF procedure indicated that infants' use of affectionate touch was significantly higher, whereas their use of playful touch was

significantly lower, during the SF period as compared to the normal and reunion periods. It appears that infants demonstrated a SF effect with regard to touch, using more affectionate and less playful touching behaviours during a period of maternal emotional unavailability. Infants' touch during the reunion period (i.e., post-SF) did not significantly differ from their touch during the normal period (i.e., pre-SF), signifying that infants' tactile behaviours returned to baseline once their mothers resumed typical engagement. These results may also be taken as providing evidence for infants' ability to effectively use touch to self-regulate during perturbed mother-infant interactions. Such findings are consistent with previous research indicating that infant tactile contact behaviours vary across the SF procedure (e.g., Trevathen, 1986; Toda & Fogel, 1993) as they use touch to regulate their affective states during the SF period (Moszkowski & Stack, 2007).

Mother-Infant Synchrony

The third and final objective was to investigate the development of mother-infant tactile synchrony. Very few studies have explored tactile synchrony among mother-infant dyads to date, and to our knowledge, there have been no studies which have examined it longitudinally and starting from their very first meeting after birth. Our findings revealed that there was a significant degree of temporal coordination between maternal and infant tactile behaviours, as the dynamic changes in infant touch patterns were significantly associated with dynamic changes of maternal touch patterns over time. Specifically, increases in maternal touch were associated with decreases in infant touch, indicating an inverse pattern of tactile synchrony over time. As previously mentioned, behavioural synchrony is *not* behavioural mimicry but is rather complex and extends well beyond mothers and infants displaying the same behaviour at the same time (Mayo & Gordon, 2020; Moore & Calkin, 2004). Interpersonal synchrony is a dynamic phenomenon which, much like touch itself, is strongly related to contextual factors (Delaherche

et al., 2012; Hoyniak et al., 2021; Mayo & Gordon, 2020). Therefore, our understanding of synchrony must be flexible and tailored to the specific context of each interaction. The inverse pattern of synchrony observed may reflect mothers and infants complementary or coordinated use of touch, whereby one adjusts their behaviour in accordance with the other (Delaherche et al., 2012; Mayo & Gordon, 2020). Given that the mothers and infants of the present study were observed following periods of perturbation involving temporary disruptions of maternal unavailability (i.e., maternal pain at Time 1, SF at Time 2), dyads may have been more inclined to engage in a reciprocal, turn-taking dynamic. It has been previously suggested that increased dyadic coordination reflects mothers' attempts to soothe and regulate their infants following periods of disruption or stress (Hoyniak et al. 2020; Manian & Bornstein, 2009). Thus, mothers may have increased their touch in tandem with decreased infant touch as a means of comforting their infants (and perhaps even themselves) from the physiological stress of labor and the social stress of the SF. The known regulatory effects of both touch and synchrony during mother-infant interactions, combined with the premature capacity of young infants' self-regulatory abilities, reinforce this as a plausible explanation (DiCorcia & Tronick, 2011).While far more research is needed to examine tactile synchrony within post-perturbation contexts, the current findings on touch fit well with prior research indicating that mother-infant dyads demonstrate increased synchrony via their affective states following the SF period (i.e., the reunion period; Moore & Calkins, 2004).

Implications, Limitations, and Future Directions

In all, the results of the present study emphasize the central role of touch starting from the first hour of life. Touch represents a primary means for newborns and parents to interact with one another for the first time. Tactile behaviours facilitate the significant life transitions experienced by each member of the family system, and correspondingly support the

implementation of essential care behaviours such as breastfeeding and soothing (as demonstrated by reduced infant crying and fussing). Through touch and starting from their very first encounter with one another, mothers and infants begin to achieve synchrony and continue to develop it across their interactions over time. Considering touch is infants' most developed communicative modality and there is no evidence to support the emergence of other forms of behavioural synchrony immediately after birth, touch may be an important mechanism through which interpersonal synchrony develops within the mother-infant dyad. Moreover, touch displayed by newborns immediately after birth appears to set the stage for their use of touch later on in infancy, as it was tied to increased displays of touch following perturbed mother-infant interactions at 3-months. These findings, combined with the results demonstrating that infants become more reliant on touch when mothers are emotionally unavailable (i.e., SF period), underscore the regulatory function of the tactile modality.

Taken together, our findings inform policy and hospital care practices promoting immediate and prolonged physical contact between parents and their newborn infants (Field, 2019; Phillips, 2013). Our findings contribute to the development of parenting intervention programs aimed at disseminating knowledge on the substantial benefits of touch, synchrony, and parent-infant interactions with regard to infants' and parents' health and well-being. Indeed, early care programs may encourage parents to engage in proximal parent-infant interactions early on in infancy, providing infants with increased opportunities to further develop their ability to use and respond to touch and enhancing the parent-infant relationship. Findings also guide health care practitioners regarding *when* such interventions ought to be implemented. Touch-based programs would be advantageous throughout early infancy yet would also be beneficial during pregnancy, prior to labor and delivery, and in preparation for the immediate postpartum period (Field, 2008). The utility of these interventions applies to all families but would be especially

critical for those at-risk, demonstrating impaired regulatory abilities and atypical exchanges (e.g., preterm or very low birth weight infants, mothers with depressive symptoms; Bigelow et al., 2012; Herrera et al., 2004; Mantis & Stack, 2018).

Future research is required to examine infant and parent touch within the immediate postpartum period amongst at-risk dyads and triads, and to determine whether and how these may differ from those described in the current study, which focused solely on healthy infants and typically developing families. It is imperative for future investigations to consider differences in how at-risk mother-infant dyads use touch to establish synchrony through touch, and to investigate tactile synchrony amongst *father*-infant dyads. Fathers within the present study were only observed within the immediate postpartum period and thus the progression of their touching behaviours over time and throughout the SF procedure could not be determined. This represents a limitation of our study and is reflective of the inadequacies of developmental research as a whole, as far less is known about how fathers use touch to interact with their infants over time and whether their touch may also have predictive qualities. It would also be important to examine touch in various familial contexts extending beyond the inclusion of fathers. For example, families comprising of same-sex couples, non-first-time parents, and siblings, as well as multigenerational homes whereby other family members may also be primary caregivers, should be better represented within the literature.

In order to expand our knowledge about the development of touch and tactile synchrony, future investigations must continue to implement longitudinal designs within interactive contexts that are both naturalistic and experimental in nature (Field, 2019). Our study significantly contributed to the literature by utilizing a longitudinal design that started from the first moments after birth to 3-months postpartum, a critical or sensitive period of development, and by focusing on two related post-perturbation contexts. More research is needed to examine how touch

displayed within this period of time relates to touch across the first year of life and throughout childhood, and how it may relate to the interactive behaviours displayed in the other caregiver-infant interaction contexts noted above. Finally, future studies ought to replicate our findings within larger sample sizes to extend their generalizability.

While there are a number of important areas for researchers to expand on, this study greatly contributes to our understanding about the tactile modality. Notably, our study is the only one to date which has described the specific types and amounts of newborn touching behaviours in the first moments to an hour *immediately* after birth and in the context of their very first triadic interaction with both their mothers *and* fathers. Our study thoroughly examined the interrelation of specific and general tactile behaviours displayed by parents and infants, yet also went beyond touch by describing behaviours tied to other modalities (i.e., infant crying and fussing, in addition to maternal vocalizations, facial expressions, and gestures for pain) and post-birth activities (i.e., breastfeeding). In addition to examining how newborn touch progresses from this period of time to 3-months later, we considered its role in the development of mother-infant synchrony, which has remained unexplored within the literature to date. Findings are derived from extremely rich behavioural observational data and consequently provide substantial insight into the complex dynamics at play within naturalistic and experimental post-perturbation contexts. The pervasiveness of newborn touch just moments after birth, as well as its ties to parental touching behaviours and contextual factors over time, unveil touch as a remarkable sensory modality.

Table 1. *Behavioural observational coding systems and adaptations for maternal and infant touch in the present study.*

Coding System				
Caregiver-Infant Touch Scale (CITS); Stack et al., 1996; Jean et al., 2009	**Caregiver-Infant Touch Scale-Adapted (CITS-Adapted);** Mercuri et al., 2019	**Infant Touch Scale (ITS);** Moszkowski & Stack, 2007	**Infant Touch Scale – Adapted (ITS-Adapted);** Mercuri et al., 2020b	
Touch Category				***Brief Description***
1.Static	1.Static	1.Static	1.Static	Touch without movement.
2.Stroke/Caress/Rub/Massage	2.Stroke/Caress 3.Massage/Rub	2.Rub/Caress/Wipe/Stroke	2.Rub/Wipe	Lateral soft and gentle movements or rubbing motion involving strong back and forth or circular movements.
3.Squeeze/Pinch/Grasp	4.Palmar Grasp Reflex	3.Grasping/Clutching/ Clasping	3.Grasping/ Clutching	All or some of fingers curled around a stimulus. Includes firmer hold or grip. Mother's finger(s) enclosed within infant's hand.
4.Tickle/Fingerwalk/Prod/ Poke/Push		4.Manipulating/Fingering/ Scrumble /Poke/Prod	4.Manipulating/Scrumble	Involves small repetitive movements, generally in a random fashion. Includes handling or extending finger(s).
5.Tap/Pat		5.Tap/Pat	5.Tap/Pat	Quick up and down motions using either palm or fingertips.
	5.Kissing	6.Mouthing	6.Mouthing/Suckling	Touch through lips, or when infant's hand comes into contact with their mouth region.
6. Pull/Lift/Extension/Clap		7. Pull/Push/Clap/Lift		Pulling or pressing of stimulus; striking hands against each other; raising a stimulus higher than its original position.
7.Shake/Wiggle				Moving part of the infant in short quick motions from side-to-side or up and down.
	6.Holding			Taking hold of infant's body or limb, or part of infant's body or limb.
	7. Utilitarian/ Instrumental			Includes adjusting infant's clothing, wiping infant's mouth, moving infant's positioning, etc.

	8. Rocking			Moving of infant's body in back-and-forth movements. Coded for mothers only.
	9.Blowing			Expelling air through pursed lips toward infant. Coded for fathers only.
			7.Flexing/Fisting	Opening and closing of hand; may include enclosed thumb and extending fingers outwardly, often in repetitive manner.
8.Other	10.Other		8.Other	Any other type of touch that cannot be classified in any of the above categories.

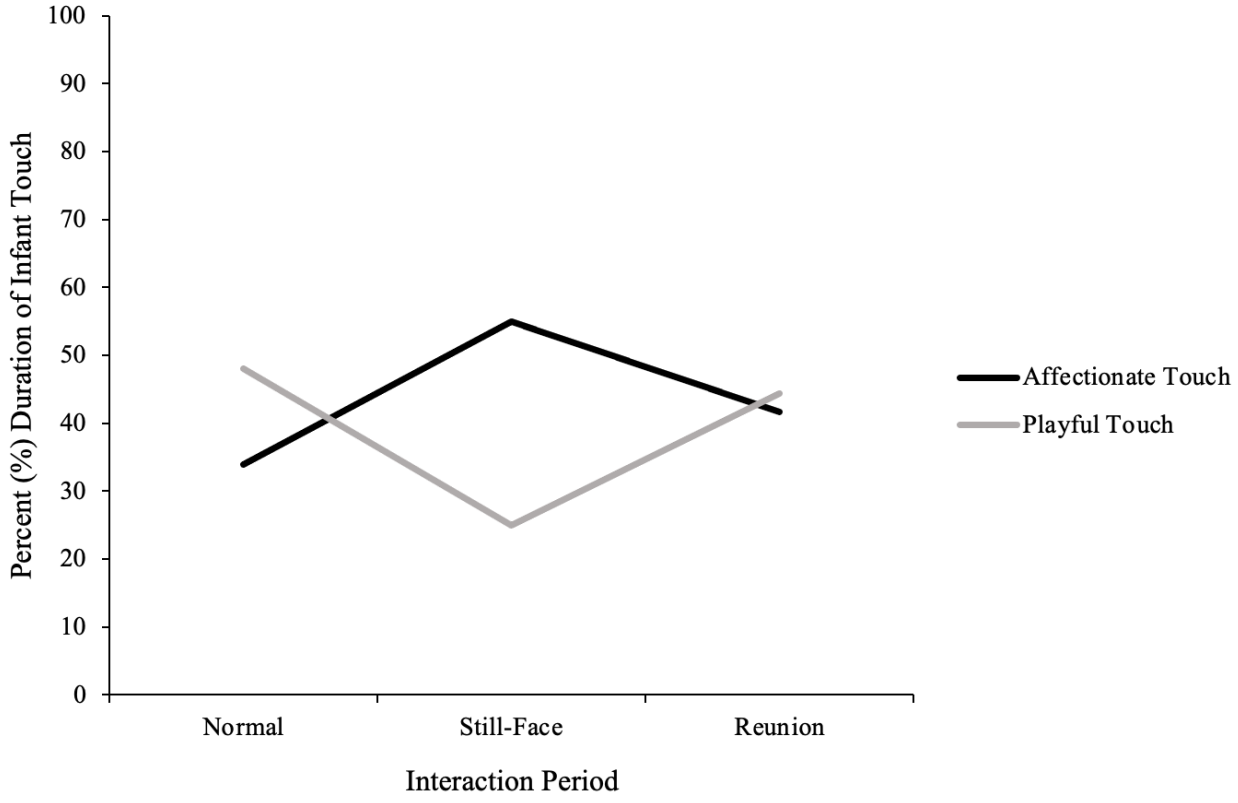
Note. The adapted versions of the CITS and ITS were based on the original versions and designed to capture touching behaviours characteristic of the immediate postpartum period. Consequently, certain types of touch included in the original versions of the CITS and ITS were excluded or replaced for more context-appropriate categories. For example, Tickle/Fingerwalk/Prod/Poke/Push and Shake/Wiggle were not included in the adapted version of the CITS, as they are playful behaviours displayed by caregivers later on in infancy rather than immediately after birth. Similarly, Pull/Push/Clap/Lift was not included in the adapted version of the ITS as this category of behaviours require more refined motor skills and coordination which also emerge later on in infancy and within playful contexts.

Table 2. *Means and standard deviations for the percent duration of newborns' touching behaviours displayed immediately after birth.*

Type of Touch	***M***	***SD***
Static	34.58%	19.09
Mouthing/Suckling	19.37%	15.80
Flexing/Fisting	17.43%	13.57
Grasping/Clasping	7.10%	10.84
Manipulating/Scrumble	6.67%	7.02
Rub/Wipe	1.59%	2.07
Tap/Pat	0.10%	0.13
Total Touch	86.83%	9.78
Cannot See	13.16%	10.15
Total	100%	

Note: The "Cannot See" category was coded either when newborns' hands were not visible or when the quality of the video diminished considerably, thereby preventing the coder from determining the specific touching behaviour displayed.

Figure 1. *Percent durations of infants' affectionate and playful touching behaviours across the normal, still-face, and reunion periods of the Still-Face procedure at 3-months postpartum.*



Chapter 5: Transition Statement Between Study 2 and Study 3

Study 2 entailed a thorough examination of newborns' earliest displays of touch in the first hour immediately following birth and delivery in a sample of healthy, typically developing infants. Findings revealed that newborns displayed a range of touching behaviours throughout the large majority of the immediate postpartum period, and at significantly higher rates than both their mothers and fathers. While a number of meaningful associations between parents' and newborns' tactile behaviours and the more global behaviours characteristic of the immediate postpartum period were found, the association between increased maternal touch and decreased infant crying/fussing most notably revealed the soothing and regulatory qualities of touch. Additionally, newborn touch positively predicted the touching behaviours of these same infants 3-months later following, but not preceding, a period of maternal emotional unavailability (i.e., still-face/SF; Tronick et al., 1978). Across these same perturbed (post-birth, post-SF) interactions over time, an inverse pattern of coordination (i.e., coordinated, converse changes in touch) between maternal and infant touch was found. This pattern of mother-infant touch synchrony may reflect a reciprocal, turn-taking dynamic driven by mothers' attempts to soothe and regulate their infants following periods of stress (physiological stress following birth, social stress following SF), yet also suggests that mothers' and infants' may have an innate or early ability to achieve synchrony through touch.

Study 3 was designed to further our understanding about the synchrony of maternal and infant touch within the context of perturbed mother-infant interactions. Whereas Studies 1 and 2 examined small samples of typically developing families and over time, Study 3 examined a larger sample of mother-infant dyads, including those at-risk due to maternal depressive symptomatology. In Study 3, mothers and their 4-month-old infants completed the SF procedure

as well as the Separation procedure (SP; Field et al., 1986), which comprises two normative face-to-face interactions separated by a brief perturbation period, during which mothers are temporarily out of their infants' field of view. Therefore, Study 3 investigated the coordination of maternal and infant touch within the context of *two* forms of social stress; that is, across periods of maternal emotional (SF) *and* physical (SP) unavailability.

Moreover, infant crying was examined across the SF and SP procedures. This aspect of infant crying builds on Study 2, which demonstrated a link between maternal touch and newborn infant crying, and builds on the extant literature, which has cited increased infant crying as a signature SF and SP effect (Lamb et al., 1987; Muir & Lee, 2003; Stack, 2010). Infant crying is a potent communicative cue that creates and signifies moments of disruption for the dyad (Augustine & Leerkes, 2019; Horowitz et al., 2019) and contributes to the dynamic changes pertaining to maternal and infant touch. Thus, Study 3 examined instances of infant crying as *micro*-level perturbation periods. In comparison to the SF and SP periods, which can be viewed as *macro*-level perturbations that are lengthier and more pronounced, infant crying represents shorter and more minimal, yet typical, moments of mild disruption or distress. At each level, misalignment is expected to occur and is likely to influence the quality and quantity of the dyad's touching patterns. Taken together, Study 3 explored how mothers and infants use touch to repair these discrete moments of misalignment and whether patterns of tactile synchrony differ according to risk via maternal depressive symptomatology.

Chapter 6: Dissertation Study 3

Maternal and infant touching behaviours during perturbed interactions: Associations with maternal depressive symptomatology and infant crying

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Manuscript submitted to *Infant Behavior & Development* and under review:

Mercuri, M., Stack, D.M., Mantis, I., Moszkowski, R., & Field, T.M. (Under review). Maternal and infant touching behaviours during perturbed interactions: Associations with Maternal depressive symptomatology and infant crying. *Infant Behavior & Development.*

Acknowledgements. The authors gratefully acknowledge financial support from: le Fonds québécois de la recherche sur la société et la culture (FRQ-SC), Social Sciences and Humanities Research Council of Canada (SSHRC), Centre for Research in Human Development (CRDH), and Concordia University for grant and funding support awarded to Dr. Dale M. Stack (PI) and co-investigators, doctoral level fellowships (SSHRC) and funding support (CRDH, Concordia University) awarded to Marisa Mercuri, and to the National Institute of Mental Health (MH46586), March of Dimes (12- FY03-48), and NIH Senior Research Scientist Awards (#MH00331 and AT#001585) for grant support awarded to Dr. Tiffany Field, and Johnson and Johnson Pediatric Institutes for funding support to the Touch Research Institute. The authors would also like to thank Olivia Lazimbat for involvement in data preparation, including behavioral observational coding, and Cassandra Zephirin for help with the preparation of this manuscript. Finally, the authors extend their deepest gratitude to the mothers and infants who generously participated in this research.

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Abstract

Touch is an important means through which mothers and infants co-regulate during periods of stress or perturbation. The present study examined the synchrony of maternal and infant touching behaviours among 41 mother-infant dyads, some of whom were deemed at-risk due to maternal depressive symptomatology. Mothers and their 4-month-old infants participated in the Still-Face (maternal emotional unavailability; SF) and Separation (maternal physical unavailability; SP) procedures. Infant crying was examined across procedures and investigated as a brief period of perturbation. Results revealed that mothers and infants displayed a positive pattern of tactile synchrony during infant crying episodes. However, dyads in the high depression group displayed significantly less affectionate touch during instances of infant crying. Furthermore, more depressive symptoms were associated with less maternal and infant touch and lower rates of infant crying. This group of dyads may be less expressive via touch, be less affected by disruptions in their interactions, have impaired regulatory abilities, or simply require minimal amounts of touch to mutually regulate following social stressors and during brief perturbation periods. These findings enrich our limited knowledge about the dynamic interplay of maternal and infant touch and inform preventative intervention programs for at-risk groups.

Introduction

Touch is a fundamental means of communication and connection between mothers and their infants (Botero et al., 2020). Its centrality to the mother-infant relationship is reflected in the fact that mothers and infants begin to interact via the tactile modality well before the infant is born (Gallace & Spence, 2016). That is, the fetus experiences and responds to tactile stimulation received through the uterine wall during maternal movement as early as 20 weeks gestation (Diego et al., 2002; Mantel et al., 2021; Marx & Nagy, 2015). At this time, the mother also feels and reacts to the fetus moving within her womb (Junger, 2020; Quintero & De Jaegher, 2020). The tactile modality remains a vital channel from birth and throughout the first year of life as the infant's ability to utilize and respond to touch becomes more refined and specialized, especially as compared to the other sensory modalities which develop subsequent to the somaesthetic system (Cascio et al., 2019; Montagu, 1986; Montirosso & McGlone, 2020). Both maternal and infant touch have been found to occur throughout the large majority, if not the entirety, of each mother-infant interaction (Jean et al., 2009; Mantis et al., 2019; Mercuri et al., 2019). Thus, touch provides the dyad with their first set of shared experiences and represents the earliest channel for reciprocal exchange.

The reciprocal nature of touch, however, has been vastly overlooked to date. That is, the limited number of studies on touch, including those published more recently, have been predominantly unidirectional, examining *either* maternal (e.g., Serra et al., 2020) *or* infant touch (e.g., Widström et al., 2020) rather than both concurrently. The employment of unidirectional as opposed to bidirectional examinations of touch represents one of the most commonly cited and longstanding limitations in the extant literature (Mantis et al., 2014; Mantis & Stack, 2018). Yet, the inherent mutuality of touch is arguably its most unique feature and further distinguishes it

from all other senses, as one cannot touch someone else without simultaneously experiencing touch themselves (Ciaunica & Fotopoulou, 2017; Crucianelli & Filippetti, 2020). While unidirectional studies contribute to our understanding of the tactile modality, they do not account for the reciprocal and dynamic influences that underlie touch, hindering our ability to draw meaning about the role and implications it has during early interactions (Stack & Jean, 2011).

Theoretical models of development provide useful frameworks for mother-infant interactions and guide more complete investigations of touch. The Mutual Regulation Model (MRM) in particular, highlights the dynamic processes embedded in mother-infant interactions (Tronick, 1989; Tronick & Weinberg, 1997). From this view, mothers and infants are understood as an integrated, mutually regulated, dyadic system that is fundamentally bidirectional. Both members of the dyad are recognized as important contributors to the nature and progression of their interactions (DiCorcia & Tronick, 2011). The dyadic interaction is considered a collective exchange of communicative signals, whereby each member of the dyad is sensitive and responsive to changes in one another's emotional and behavioural states (Gianino & Tronick, 1988). By being jointly guided by the other's expressive displays, mothers and infants form a synchronous behavioural dialogue (Hsu & Fogel, 2001; Tronick & Beeghly, 2011).

Synchrony

Synchrony entails coordinated behavioural and affective states between a caregiver and their infant (Nguyen et al., 2021). It is a key dynamic process implicated in the formation of secure attachment (Isabella & Belsky, 1991) and bonding (Feldman, 2017) between mothers and their infants. Synchrony extends beyond mimicry or simultaneous engagement of a particular behavioural or emotional state (Mayo & Gordon, 2020; Moore & Calkins, 2004). It is better described as the rhythmic pattern that develops within mother-infant interactions and the

reciprocal interplay between their respective behaviours (Hoehl et al., 2021). Indeed, typical mother-infant interactions involve fluctuations between matched and mismatched states (Montirosso & McGlone, 2020). It is through this process of repairing interactive incongruences that the infant's regulatory capacities are scaffolded and the dyad's ability to achieve synchrony is exercised (Müller et al., 2015; Provenzi et al., 2016).

Infant Crying

Infant crying represents a crucial context that provides dyads with the opportunity to engage in the mutual regulation process and re-establish synchrony. Crying is a potent communicative cue which both reflects and creates moments of disruption for the dyad (Augustine & Leerkes, 2019; Horowitz et al., 2019). It is a communicative means whereby infants express distress or discomfort (DiCorcia & Tronick, 2011). Crying episodes are also micro-stressors in and of themselves as they temporarily disrupt the organization of the dyad's co-regulatory system; this context of crying provides the dyad with the opportunity to learn how to navigate a rupture in their interaction, transform it back to a non-stressful state, and resume a coordinated pattern of communication (DiCorcia & Tronick, 2011; Gianino & Tronick, 1988; Montirosso et al., 2010). The primordiality of the somaesthetic system and the regulatory functions of the tactile modality underscore touch as a primary tool used by the dyad to repair their misaligned states and restore harmonious interactions (Nguyen et al., 2021).

Although maternal and infant touch are central to the mutual regulation process, and infant crying is a common yet powerful period of disruption, tactile synchrony has yet to be examined during the bouts of crying that occur throughout mother-infant interactions (Field, 2010; Harder et al., 2015; Leclère et al., 2014). As such, an investigation of *tactile synchrony,* or the degree of coordination between mothers' and infants' respective touching behaviours, within

the context of infant crying is warranted. This represents an important area of investigation considering that mother-infant touch during brief disruptions such as these has the potential to foster resiliency and self-efficacy within the infant and enhance the quality of the mother-infant relationship (Tronick & Beeghly, 2011). Conversely, touch within the context of communicative ruptures such as infant crying represents a potential mechanism through which risk may be transferred to infants (Milgrom et al., 2004; Turney, 2011). That is, mothers and infants must appropriately interpret and respond to one another's communicative cues to successfully repair disruptions in their interactions and return to synchrony (Leclère et al., 2014; Weinberg et al., 2006); when mothers and infants are regularly unable to use touch to repair disruptions in their interactions, such disruptions may become chronic and lead to negative cascading processes that ultimately impair social, behavioural, and emotional development (DiCorcia & Tronick, 2011). Thus, it is also imperative that maternal and infant touching patterns during bouts of infant crying are explored among at-risk, and not just typically developing, dyads.

Maternal Postpartum Depression

Postpartum depression represents one of the more common forms of psychopathology placing mother-infant dyads at-risk regarding their ability to repair disruptions throughout their interactions (Granat et al., 2017; Laurent & Ablow, 2012). Research on the emotional states of mother-infant dyads has demonstrated that exposure to postpartum depression is associated with less emotional repair, more prolonged periods of negative affect, and more time needed to repair mismatches in their emotional states (Feldman et al., 2009). In part, these difficulties have been attributed to findings linking maternal depressive symptomatology to reduced maternal sensitivity and responsiveness, impaired regulatory abilities, and desynchronized mother-infant interactions (Pearson et al., 2012; Ntow et al., 2021; Viaux-Savelon et al., 2016). Furthermore,

mothers with high levels of depressive symptomatology have been found to have atypical communicative patterns, displaying fewer visual and vocal communicative behaviours when interacting with their infants (Field, 2010). The few studies which have investigated the early touch patterns among this vulnerable at-risk population have mostly centered around identifying the inadequacies in the amount and type of touch used by depressed mothers when interacting with their infants (Fantasia et al., 2019). In general, the touching patterns of depressed mothers have been described with negative constructs such as intrusive, withdrawn, or disengaged (Field, 2010).

In line with the overall state of the touch literature, those studies which have considered touching behaviours among depressed mother-infant dyads have also entailed unidirectional investigations of maternal touch and have neglected infant touch altogether. Fantasia and colleagues (2019) argue that results from studies which have examined maternal behaviours alone and in isolation from infant behaviour may not be able to adequately characterize depressed mother-infant interactions given that the reciprocal nature of their social exchanges is not fully accounted for. The dynamic processes of touch, and tactile synchrony in particular, have yet to be examined in relation to maternal depressive symptomatology. Therefore, it is not yet clear whether postpartum depression impedes on mothers' and infants' ability to repair disruptions in their interactions specifically through touch, their most familiar channel of communication and an essential component of the mutual regulation process. The early interaction patterns that develop among depressed dyads are important to investigate as they can remain even when depressive symptoms subside (Mantis et al., 2019; Weinberg & Tronick, 1996), and depending on how they unfold, have the potential for adverse long-term consequences (Field, 2019; Horowitz et al., 2019). Bidirectional investigations are thus crucial to

obtain a more accurate understanding of how mothers with postpartum depression utilize touch, how their use of touch directly compares to the touching patterns of their infants, and to what extent these patterns align during periods of stress or perturbation.

Still-Face and Separation Procedures

Face-to-face mother infant interactions, such as the Still-Face (SF; Tronick et al. 1978) and Separation (SP; Field et al., 1986) procedures, are powerful paradigms for studying how dyads use touch to cope with stress (Montirosso et al., 2010). Both procedures consist of three sequential mother-infant interactions, beginning with a normative social exchange during which mothers and infants engage with one another as they typically would (Ntow et al., 2021). This normative period is immediately followed by a perturbed interaction characterized by maternal unavailability. In the SF procedure, the perturbed interaction period entails emotional unavailability as mothers maintain a still, neutral, and unresponsive facial expression while gazing at their infant and abstain from communicating through the tactile and vocal modalities. In the SP procedure, mothers are physically unavailable to their infants by briefly separating from their infant such that they cannot be seen or heard (Mantis et al., 2019). A final "reunion" period subsequently follows the perturbation in each of these two procedures, whereby mothers and their infants are able to re-engage with one another and reinstate a normal interaction.

Although brief in duration, the perturbation periods have generally been found to produce mild stress effects among infants, including increased gaze aversion, motor activity, and crying (Field et al., 1986). Previous studies have demonstrated that these same displays of stress tend to carry-over into the reunion period as infants continue to cope with the dyadic disruption incurred in the perturbation period, demonstrating a *reunion effect* (Adamson & Frick, 2003; Montirosso et al., 2010). The infant's stress-related behavioural repertoire from the perturbation is also

observed when mothers become re-engaged; infants reportedly remain mildly stressed even after being able to resume regular communication (Feldman et al., 2010; Weinberg & Tronick, 1996). Notably, infant crying persists and represents the most powerful signal of social stress within the reunion period (Cecchini et al., 2007; Field et al., 2007).

From a practical standpoint, the SF and SP procedures offer researchers the opportunity to explore the coordination between maternal and infant touch within the context of varying levels of perturbation. The crying episodes that occur within the reunion period (as part of the significant SF/SP effect; Muir & Lee, 2003) may be regarded as *micro-level perturbations* because they are short and discrete, yet also representative of typical displays of mild infant stress. The reunion period itself is an interactive context that can be viewed as a *macro-level perturbation* being that it is lengthier in comparison and, given the reported carry-over effects of infant crying (Cecchini et al., 2007; Field et al., 2007), are representative of a more pronounced form of social stress. Both levels of perturbation represent moments of emotional and physical misalignment (Montirosso et al., 2010) that are expected to influence the quality and quantity of the dyad's touching patterns, and by extension, inform the regulatory quality of the interaction (Müller at al., 2015). To our knowledge, this study represents the first to offer this framework of micro- and macro-level perturbations for the study of touch and mother-infant interactions.

The Present Study

The present study was formulated to examine whether and to what extent maternal depressive symptomatology influences mothers' *and* infants' use of touch in the context of perturbed mother-infant interactions. Specifically, the synchrony of maternal and infant touch during micro-periods of stress (i.e., infant crying) that occur within the macro-level perturbation context of varying forms of maternal unavailability (i.e., reunion period following maternal

emotional and physical unavailability via the SF and SP procedures) were considered. Consistent with previous research, mothers and their infants in the current study were classified in one of two groups: high or low depressive symptomatology (Field et al., 2007; Mantis et al., 2019; Moszkowski et al., 2009).

The first objective was to examine whether infants in the high depression group differ from those in the low depression group regarding their rates (percent duration) of crying. Crying is an integral form of communication during infancy; research suggests that an atypical trajectory of crying may signify aberrant development (Esposito et al., 2013). However, there have been mixed findings reported among the very few studies investigating crying in infants of depressed mothers; Field and colleagues (2007) found that this population of infants demonstrated lower rates of crying, whereas Esposito et al. (2017) found that they demonstrated comparable rates of crying compared to infants of non-depressed mothers. In the present study, it was hypothesized that infants of mothers with higher levels of depressive symptomology would be less distressed by the perturbation period and would therefore demonstrate less crying in duration throughout the reunion periods of the SF and SP procedures.

The second objective was to examine the quality (type of touch) and quantity (duration of touch) of mothers' and infants' touch during instances of infant crying. The aim was to examine whether maternal and infant touching behaviours were synchronous and whether tactile synchrony varied according to mothers' depressive symptomatology. This objective represents a unique yet important contribution to the literature given that no other study (to our knowledge) has simultaneously examined maternal and infant touching behaviours in relation to maternal depression while also considering the context of infant crying. The significance of this objective is further underscored by the centrality of both touch and synchrony to infants' social and

emotional development, the lack of research on the interrelation of maternal and infant touch during crying episodes, and the risks associated with depressive symptomatology. Based on the link between maternal depression and reduced maternal responsiveness, it was hypothesized that dyads with higher levels of depressive symptomatology would be less inclined to use touch during instances of infant crying. Drawing from previous findings indicating associations between maternal depression and reduced behavioural synchrony (Ntow et al., 2021; Wan et al., 2013; Viaux-Savelon et al., 2016), the touching behaviours of dyads in the high depression group were also expected to be less coordinated in comparison to dyads in the low depression group.

Method

Participants

This study was conducted in accordance with the ethical standards of the American Psychological Association, and after approval by the institutional ethics review board at the Touch Research Institute, University of Miami School of Medicine. Following ethics review and approval, mothers provided their informed consent (see Appendix C for consent form). Forty-one mothers and their 4-month-old infants participated in the current study. Participant recruitment took place prenatally and within ultrasound clinics at the University of Miami School of Medicine in Miami, Florida, USA. Mothers were classified with either high (n=13) or low (n=28) levels of depressive symptomatology using a questionnaire measure (see Measures section below). Regarding infant sex, 20 were male and 21 were female. Mothers were aged 18 to 41 (M = 24.88, SD = 5.97) years and their infants' ages averaged 17 weeks (SD = 1.33). Mothers varied in terms of ethnicity: 46% Hispanic, 46% African American and 8% White. Participants were of lower socioeconomic status and on average, completed secondary level education.

Measures

Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977)

The CES-D is a valid and reliable self-report questionnaire that measures the number of depressive symptoms experienced by caregivers over the past week, with higher scores indicating higher levels of depressive symptomatology. In other samples, the CES-D has been found to have a very high internal consistency ($\alpha = 0.80$ to 0.90) and has been regarded as a valid measure of depressive symptomatology. In accordance with the CES-D guidelines (Lewinsohn et al., 1997) and previous studies using this measure (e.g., Field et al., 2007; Mantis et al., 2019; Moszkowski et al., 2009), a clinical cut-off score of 16 or more was used to classify high levels of maternal depressive symptomatology.

Apparatus

A video camera captured and recorded a series of mother-infant interactions. Videotapes were subsequently digitized and transferred onto a computer. The recordings were then reviewed for behavioural coding using Mangold INTERACT, a professional software system for behavioural research that allows qualitative and quantitative analysis of multimedia data.

Procedure

Data Collection

Following completion of a demographic questionnaire and the CES-D, mothers and their infants participated in the Still-Face (Tronick et al., 1978) and Separation (Field et al., 1986) procedures in the laboratory at the Touch Research Institute at the University of Miami School of Medicine (USA). Procedures were counterbalanced across mother-infant dyads, and were separated by a 3-minute interval, to control for order, state, and fatigue effects. In both

conditions, infants were securely fastened in an infant seat on a table, directly facing their mother at eye-level, and at a distance of approximately 46 cm.

The Still-Face procedure comprises three face-to-face mother-infant interactions: the normal, still-face, and reunion periods. During the normal and reunion periods, mothers were instructed to play with their infant as they normally would at home. During the still-face period, mothers were instructed to gaze at their infant while maintaining an expressionless or neutral facial expression and while refraining from using any other form of communication including vocalizations and touch. Despite being physically present, mothers were unresponsive and emotionally unavailable to their infants at this time. The Separation procedure similarly comprises three interactions: the normal, separation, and reunion periods. Mothers were given the same instructions for the normal and reunion periods of this procedure. During the separation period, mothers were instructed to step away from their infant, hide behind a curtain, and remain silent and out of their infants' view. Mothers were thus physically unavailable to their infants at this time.

All periods in each procedure were 90 seconds long. The experimenter indicated the beginning and end of each period by knocking on the one-way mirror. Interactions were captured using two cameras, each positioned on tripods in the periphery of the dyad's fields of vision.

Observational Coding

Behavioural coding was completed in the Infant and Child Studies Laboratory at Concordia University (Montreal, Canada). Video records were reviewed prior to coding to ensure maternal compliance with the instructions of each procedure. Maternal and infant touching behaviours, in addition to infant crying, were coded by three of the authors, all of whom were blind to mothers' group classification based on CES-D scores.

The Caregiver-Infant Touch Scale (CITS; Stack et al., 1996) was used to code maternal touch, whereas the Infant Touch Scale (ITS; Moszkowski & Stack, 2007; Moszkowski et al., 2009) was used to code infant touch. Both the CITS and the ITS are reliable and systematic coding systems which entail second-by-second analysis and measure the qualitative and quantitative changes in tactile stimulation produced by caregivers and infants during their social interactions. Table 1 provides a description of the individual types of maternal and infant touching behaviours.

The Infant Cry Scale (ICS; Mercuri & Stack, 2020) was used to code infant crying. Consistent with Esposito and colleagues (2017), infant crying was coded when negatively toned vocalizations persisted for at least 1 second in duration. While the codes were based primarily on auditory information, visual contextual cues from both the infant and mother were utilized to ensure accuracy. For example, vocalizations emitted while infants were smiling were not considered crying. Codes were entered as soon as a negatively toned vocalization was heard and maintained until 10 seconds or more passed without continued vocalization. In such cases, the end of the code was marked by the end of the last vocalization of a particular crying sequence. Unlike the CITS and ITS, videos were reviewed in real-time rather than second-by-second; the speed was adjusted to capture precise start and end times for each code.

Coders were first trained on the coding systems to reach a high level of reliability before formal coding commenced. When discrepancies between raters occurred during this training period, coders reviewed the corresponding portion of the video second-by-second, discussed, and deliberated the appropriate code for the specific segment on the video, and subsequently re-coded that portion of the video with the mutually agreed upon category. To establish inter-rater reliability, a trained second coder double coded 30% of randomly chosen video recordings of

mother-infant interactions. A very high inter-rater reliability between coders was determined for each of the coding systems overall, and for each of the individual types of codes within each system (k = 0.80 to 0.93; kappa; Cohen, 1960).

Results

Data Preparation

To facilitate data analysis and cross-study comparisons, individual touching behaviours were aggregated into composite touch variables representing mothers' and infants' total or overall touch (i.e., the sum of all individual types described in each touch-based coding system above). In line with previous investigations of touch (Mantis et al., 2019; Mercuri et al., 2019; Moszkowski & Stack, 2007; Moszkowski et al., 2009), touching behaviors were also classified as either affectionate or playful (see Table 1). Affectionate touch is characterized by lower paced contact behaviours, whereas playful touch involves more engaging and effortful contact behaviours. Our use of these categorizations of touch is supported by previous investigations utilizing affectionate and playful types of touch and which have yielded meaningful findings (i.e., Mantis et al., 2019; Moszkowski & Stack, 2007; Moszkowski et al., 2009).

Conditional probabilities were computed as an index of the co-occurrence of touch during instances of crying. Variables were computed using the percent duration of maternal touch, infant touch, and infant crying. Percent duration refers to the percentage of time over the length of the interaction period for each dyad that was allocated to a specific type of touch. It was calculated by dividing the raw duration of a specific touch category divided by the length of the corresponding interaction period (and multiplying by 100). Percent durations were calculated for each type of touch and for infant crying to control for any minimal differences in the length of the interaction periods at each interaction time point (Herrera et al., 2004; Mercuri et al.,

2019). Co-occurrence variables were subsequently computed by multiplying the percent duration of touch by the percent duration of infant crying pertaining to a specific interaction period. These co-occurrence variables represent the proportion of time a specific category of touch occurred while infant crying was also occurring. These formulas were obtained from and applied via Mangold INTERACT, the same software used for behavioural observational coding. The data preparation approach described here is consistent with previous studies examining the co-occurrence of maternal and infant behaviours (e.g., Feldman et al., 2010; Granat et al., 2017; Moszkowski et al., 2009).

Statistical Analyses

A series of mixed analyses of variance (ANOVA) were conducted to determine differences between and within groups with regard to infant crying and maternal and infant touch across periods of the SF and SP procedures. Group (High or Low maternal depressive symptomatology), Partner (Mother, Infant), and Procedure (SF or SP) were used as between-subjects variables, whereas Period (Normal, Perturbation, and Reunion) was used as a within-subjects variable. The percent durations of infant crying, maternal touch during infant crying, and infant touch during infant crying were each used as dependent variables. The specific set of variables used in each analysis varied according to the objective (see below). To maximize power, the number of factors used in each model was limited to a total of 3. For a portion of the analyses, Procedure was used as a between-subjects factors due to missing data for one of the procedures for 12 participants (n = 5 mother-infant dyads participated in the Still-Face procedure only; n = 7 mother-infant dyads participated in the Separation procedure only). For those dyads that participated in both procedures (n = 29), only data from the first procedure was included to rule out order and fatigue effects (n = 15 for dyads who participated in the Still-Face procedure

first; n = 14 for dyads who participated in the Separation procedure first). The number of dyads who participated in the Still-Face procedure (n = 20) was roughly equal to the number of dyads who participated in the Separation procedure (n = 21). For all ANOVA analyses, statistically significant main effects and interactions were followed up with post hoc tests to isolate the source of the significance. Bonferroni corrections were performed to reduce the occurrence of Type 1 errors. This statistical approach is consistent with previous studies within the literature which have assessed maternal and infant touch in relation to maternal depression using the SF and SP paradigms (e.g., Jean et al., 2009; Mantis et al., 2019; Mercuri et al., 2019).

Pearson correlations were conducted to examine the relationship between CES-D scores, infant crying, and maternal and infant touch. Pearson correlations were also importantly used as an index of tactile synchrony. According to Davis and colleagues (2018), this statistical approach is commonly used to examine behavioural and physiological forms of synchrony. Karger (1979) operationalized synchrony as the correlation between the rates of maternal and infant behaviours during corresponding segments of an interaction period. The correlation coefficient represents the degree to which members of a dyad share similar patterns of change, or the extent to which their behaviours are coordinated (Helm et al., 2018; Moore & Calkins, 2004). Correlations reflect the average magnitude and direction of synchrony for a given sample (Davis et al., 2018). A correlation coefficient ±.32 or above is considered an optimal pattern of mother-infant synchrony (Karger, 1979).

Data were screened for integrity and to ensure that the assumptions of mixed ANOVAs and correlations were met. The data cleaning process involved checking for outliers, or scores more than 3 standard deviations away from the mean. Standardized scores were used to identify outliers. Outliers were retained and adjusted by changing their values to the next highest score

(Kline, 2009; Tabachnick & Fidell, 2001). Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS, version 26.0). Results were considered statistically significant at a critical alpha level of .05 and partial eta squared (η_p^2) was used as a measure of effect size.

Objective 1: Influences of maternal depressive symptomatology on infant crying across normative and perturbed mother-infant interactions

1.1 Analyses of Variance. A 2 (Group: High or Low depression) x 2 (Procedure: SF or SP procedure) x 3 (Period: Normal, Perturbation, and Reunion) mixed-subjects ANOVA was conducted on the percent duration of infant crying, with Group and Procedure as the between-subjects factors and Period as the within-subjects factor. Results revealed a statistically significant main effect of Period only, $F(2, 74) = 9.35$, $p = .000$, $\eta_p^2 = .202$. Post-hoc analyses indicated that, as compared to the Normal period ($M = 5.48$, $SE = 2.04$), infants cried significantly more during the Perturbation period ($M = 27.78$, $SE = 5.38$; $p = .001$) and the Reunion period ($M = 25.49$, $SE = 5.95$; $p = .004$). The Perturbation and Reunion periods did not significantly differ from one another ($p > .05$).

1.2 Correlations. Correlations were conducted to examine the association between CES-D scores and the percent duration of infant crying in the Normal, Perturbation, and Reunion periods. Results revealed a statistically significant negative correlation between CES-D scores and Total Infant Crying during the Reunion period, $r = -.362$, $p = .022$; higher levels of maternal depressive symptomatology were associated with lower levels of infant crying across the Reunion periods. CES-D scores were not correlated with infant crying during the Normal period or the Perturbation period across procedures ($p > .05$).

Objective 2: Association between maternal depressive symptomatology and maternal and infant touch during instances of infant crying following maternal unavailability

2.1 Analyses of Variance. A 2 (Group: High or Low depression) x 2 (Partner: Mother, Infant) x 2 (Period: Normal, Reunion) mixed ANOVA was conducted on the percent duration of *playful* touch during instances of infant crying; Group and Partner were entered as the between-subjects variables and Period was entered as the within-subjects variable. Given the results of Objective 1 and small sample size, Procedure was not retained as a factor. Period included two rather than three levels given that mothers were instructed to abstain from using touch during the Perturbation period. Results revealed a main effect of Period only, $F(1, 78) = 14.15$, $p = .000$, $\eta_p^2 = .154$. Post-hoc analyses indicated that a higher proportion of playful touch during infant crying was displayed by dyads in the Reunion period (M= 8.37, SE = 1.75) than in the Normal period (M = 2.08, SE = .66).

A 2 (Group: High or Low depression) x 2 (Partner: Mother, Infant) x 2 (Period: Normal, Reunion) mixed ANOVA was conducted on the percent duration of *affectionate* touch during instances of infant crying; Group and Partner were entered as the between-subjects variables and Period was entered as the within-subjects variable. Results revealed a main effect of Period, $F(1, 78) = 12.09$, $p = .001$, $\eta_p^2 = .134$; more affectionate touch during crying was displayed in the Reunion period (M = 7.27, SE = 1.56) than in the Normal period (M = 1.76, SE = .69). Moreover, a main effect of Group was found, F (1, 78) = 4.43, $p = .039$, $\eta_p^2 = .054$. Post-hoc analyses indicated that dyads in the low depression group displayed more affectionate touch during crying (M = 6.43, SE = 1.02) than dyads in the high depression group (M = 2.60, SE = 1.50).

2.2 Correlations.

2.2.1 Maternal Touch. CES-D scores negatively correlated with maternal playful touch during total infant crying in the Reunion period (collapsed across procedure), $r = -.392$, $p = .012$, indicating that higher depression scores were associated with lower levels of maternal playful touch during infant crying in the Reunion period.

2.2.2 Infant Touch. CES-D scores negatively correlated with infant playful touch during crying in the Reunion period (collapsed across procedure), $r = -.411$, $p = .008$; higher depression scores were associated with less infant playful touch during infant crying in the Reunion period. CES-D scores were also negatively correlated with infant affectionate touch during crying in the Reunion period (collapsed across procedure), $r = -.453$, $p = .003$; higher maternal depression scores were associated with less affectionate infant touch during infant crying in the Reunion period.

2.2.3 Tactile synchrony. Correlations were conducted separately by group to examine the strength and direction of coordination between total maternal and total infant touch (Davis et al., 2018). The total amounts of maternal touch were obtained by summing all individual types of touch to form one total touch category; this same process was repeated for infant touch.

High Depression Group. During instances of infant crying in the Reunion period, total infant touch was positively correlated with total maternal touch, $r = .688$, $p = .009$; more infant touch was associated with more maternal touch while infants were crying following a brief period of maternal unavailability.

Low Depression Group. During instances of infant crying in the Reunion period, total infant touch was positively correlated with total maternal touch, $r = .835$, $p = .000$; more infant touch was associated with more maternal touch while infants were crying following a brief period of maternal unavailability.

Discussion

In the current study, we examined whether and how maternal depressive symptomatology was associated with infant crying during normative and perturbed mother-infant face-to-face interactions (Objective 1). We also examined maternal depressive symptomatology in relation to mothers' and infants' synchronous use of touch in the contexts of infant crying and maternal unavailability (Objective 2). To our knowledge, this study was the first to simultaneously examine both maternal and infant touch across periods of micro- (i.e., infant crying) and macro-level (i.e., Still-Face and Separation) perturbations.

The results pertaining to the first objective revealed that in general, infants cried more in the Perturbation and Reunion periods than in the Normal period. This increase in infant crying was found regardless of the kind of maternal unavailability infants were exposed to (i.e., emotional or physical) or the classification of their mothers' depressive symptomatology (i.e., high vs. low levels). When examining maternal depressive symptomatology as a continuous variable, more depressive symptoms (i.e., higher CES-D scores) were associated with lower rates of infant crying following maternal unavailability (i.e., Reunion period across both procedures). Although there was no statistically significant difference between groups when using a clinical cut-off score, more maternal depressive symptoms were associated with lower rates of infant crying following a period of maternal unavailability, providing support for our first hypothesis.

Our findings suggest that while infants generally cry more following perturbed mother-infant interactions, crying may be less pronounced or less likely to occur among infants whose mothers have more marked depressive symptomatology. Our results are in line with findings reported by Field and colleagues (2007), indicating that 4-month-old infants of depressed mothers emitted less crying during the still-face and reunion periods of the Still-Face paradigm.

Jones (2012) examined infants' responses to a different kind of social stressor and found that newborn infants of depressed mothers responded with less vocal distress following exposure to another infant's cry. Esposito and colleagues (2017) examined infant crying during naturalistic interactions in the home setting and found no statistically significant differences between 5-month-old infants of depressed and non-depressed mothers regarding the duration of their cries. Interestingly, we did not find an association between maternal depressive symptomatology and infant crying during the normal mother-infant interaction that took place prior to maternal unavailability. Variations in the quantity of infant crying in relation to maternal depression may thus be more likely to emerge within contexts that expose infants to some form of social stress.

There are several possible explanations for the negative association found between infant crying and maternal depressive symptoms. One possibility is that infants of mothers with more depressive symptoms may have been less distressed by maternal unavailability due to being more accustomed to experiencing sudden changes in their mothers' emotional and physical states, or similarly, more able to habituate to their mothers' behavioural changes (Field et al., 2007). Based on previous findings that infants of depressed mothers are less attentive to changes in facial expressions, these infants may have also been less likely to notice shifts in their mothers' emotional and physical availability (Hernandez-Reif et al., 2006). Alternatively, infants of mothers with more depressive symptoms may have been less inclined to express their distress through crying as they may be more prone to inhibiting their emotional expressions in response to mild social stressors (Jones, 2012). Lundy and colleagues (1996) demonstrated that newborn infants of mothers with depressive symptoms were less expressive in terms of their own facial expressions prior to crying episodes. Furthermore, Milgrom and colleagues (1995) found that although infants of depressed mothers displayed significantly more pronounced crying patterns

at 3-months of age, they no longer differed from infants of non-depressed mothers at 6-months of age. The authors proposed that the former group of infants learned that crying was not a useful strategy and eventually reduced their use of this mode of communication (Milgrom et al., 1995; Oberlander, 2005).

As for the second objective, results revealed that mothers and infants are generally more inclined to use both playful and affectionate types of touch during instances of infant crying occurring immediately following, rather than prior to, maternal unavailability. However, mothers and infants in the high depression group displayed significantly less affectionate touch during instances of infant crying occurring within the Reunion period and thus immediately subsequent to a period of maternal unavailability. Accordingly, more maternal depressive symptoms (i.e., higher CES-D scores) were associated with lower levels of maternal playful touch as well as lower levels of infant playful and affectionate touch during instances of crying. As such, mothers and infants demonstrated similar patterns of touch in relation to depressive symptoms. Moreover, our findings revealed that dyads in both groups had coordinated touching behaviours within the context of infant crying. Mothers and infants appear to use touch in a synchronized manner: increases in the rate of maternal touch were associated with increases in the rate of infant touch. Based on previous operationalizations of dyadic synchrony (Davis et al., 2018; Karger, 1979), both groups in the current study demonstrated a strong positive pattern of tactile synchrony. Therefore, our second hypothesis was also partially supported. As predicted, dyads with higher levels of depressive symptomatology were less inclined to use touch in response to infant crying. Yet, contrary to expectations, dyads in the high depression group demonstrated comparable patterns of tactile synchrony as those in the low depression group. Both groups demonstrated strong, positive patterns of synchrony using touch in the context of brief perturbations at the

micro- and macro-levels, suggesting that maternal depressive symptomatology may not necessarily impair dyads' ability to coordinate their use of touch during momentary disruptions (i.e., bouts of infant crying).

Our ability to fully compare these results to the extant literature is rather limited as few studies have examined mother-infant touch from a bidirectional perspective, especially among at-risk groups. Mantis and colleagues (2018) conducted one of the only studies of this kind; they investigated full-term and very low-birthweight (VLBW) preterm infants using the SF procedure at 5½-months postpartum. Their findings revealed that while all dyads jointly used touch as a means of regulating infant affect following brief maternal emotional unavailability, the touching behaviours of dyads in the VLBW/preterm group were less balanced. The results from the present study illustrated variations in maternal and infant touch patterns following brief disruptions in their interactions according to psychosocial risk. No other study, to our knowledge, has simultaneously examined maternal and infant touching behaviours in relation to *maternal depression*. Moszkowski and colleagues (2009) and Mantis and colleagues (2019) independently examined infant and maternal touch within this same sample, respectively. The former study revealed that compared to their counterparts, infants of depressed mothers used more active types of touching behaviours during periods of maternal unavailability (i.e., Perturbation periods); the latter study revealed that depressed mothers engaged in less playful/stimulating types of touch following the period of perturbation (i.e., Reunion periods). The authors postulated that such infants are less able to self-regulate through touch (Moszkowski et al., 2009) and have mothers that are either less responsive or less able to maintain playful/stimulating touch (Mantis et al., 2019). To elucidate what may explain the previously established group differences, the current study expanded on these findings and took new steps

by exploring the interrelation of maternal and infant touch patterns and how such patterns unfold during infant crying.

Findings from the present study suggest that, when examining micro-periods of infant crying, higher levels of depressive symptomatology are associated with lower rates of both maternal and infant touching behaviours. These results are in line with Esposito and colleagues (2017); they demonstrated that clinically depressed mothers use less touch and engage in fewer caregiving behaviours in response to their infants' cries. The lower rates of affectionate touch displayed by dyads in the high depression group may be reflective of their limited ability to effectively use touch as a means of emotion regulation during their interactions, or perhaps a tendency to rely on independent rather than dyadic emotion regulation strategies. In a previous investigation of infant emotion regulation, 5-month-old infants of clinically depressed mothers were found to rely on internally directed self-soothing strategies, defined as active mouthing or repetitive manipulation of a body part or object, whereas infants of mothers without a clinical diagnosis of depression used attentional regulatory strategies which elicited soothing responses from their caregivers (Manian & Bornstein, 2009). Tronick and Gianino (1986) suggest that self-directed regulatory behaviours become strengthened in infants of depressed mothers because their interactive attempts are not consistently met with appropriate maternal responses across their interactions over time. Self-directed forms of regulation may therefore be adaptive for these infants in the context of perturbed dyadic interactions (Manian & Bornstein, 2009). Under these assumptions, 4-month-old infants of mothers with high levels of depressive symptomatology, including those participating in the present study, likely require less soothing from their mothers to return to baseline and recover from perturbations.

The positive pattern of tactile synchrony observed among depressed dyads in the present study may be suggestive of infants' ability to adapt to suboptimal developmental conditions (Horowitz et al., 2019). Earlier research suggests that infants quickly develop interaction styles that are closely tied to their mothers' styles of engagement (Cohn & Tronick, 1983). It is argued that infants of depressed mothers appear to adopt "depressive-like" behaviours themselves very early on in infancy (Lundy et al., 1996). The infant's negative reaction to their mother's depressive behaviour may strengthen her depressive behaviour. By expressing less vocal distress and displaying fewer tactile behaviours (the latter as observed in the present study), infants provide their mothers with fewer, less potent communicative signals to respond to. Consequently, interaction patterns defined by limited reactivity and more muted expression may be reinforced, regardless of whether maternal attunement improves following remission of postpartum depression (Horowitz et al., 2019; Lundy et al., 1996). While fewer interactive behaviours may be adaptive for infants of depressed mothers in the context of mother-infant interactions, it may place them at a disadvantage during future interactions with other partners later in their development (Manian & Bornstein, 2009).

Given the numerous benefits associated with interpersonal synchrony and positive childhood health outcomes linked to social, cognitive, and behavioural development (Leclère et al., 2014), it is still encouraging that mothers and infants in the high depression group demonstrated similar patterns of tactile synchrony in both magnitude and direction to those in the low depression group. These findings suggest that, in the context of maternal emotional and physical unavailability, depressed dyads coordinate their touching behaviours and use touch as a means of repairing brief disruptions in their face-to-face interactions (DiCorcia & Tronick, 2011). Effective reparation and the establishment of synchrony requires mothers and infants to

mutually interpret and respond to one another's communicative cues (Müller et al., 2015; Provenzi et al., 2016). A previous study with this same data set supports this interpretation, as depressed and non-depressed mothers did not significantly differ in maternal responsiveness and sensitivity (Moszkowski et al., 2009) as measured by the Emotional Availability Scales (EA scales; Biringen et al., 2014). Taken together, depressed dyads appear to have the capacity to appropriately respond to one another, and using dynamic behavioural processes embedded in the tactile modality, successfully adapt to challenges (Masten et al., 2021). However, depressed dyads may have difficulty sustaining tactile synchrony and maintaining coordinated levels of engagement beyond brief moments of disruption and within the context of prolonged face-to-face interactions. Indeed, previous research suggests that depressed mothers are less likely to sustain high levels of touch across their interactions with their infants (Mantis et al., 2019) as they are more likely to experience fatigue and loss of energy (Pearlstein et al., 2009). Nonetheless, the present findings may reflect signs of *resiliency,* which entails the use of multilevel and systemic processes to obtain better-than-expected outcomes despite adversity, including those tied to maternal psychopathology (van Breda, 2018). Our study adds to the emerging line of research highlighting the social and emotional competencies of at-risk groups (Fantasia et al., 2019; Mantis et al., 2019; Masten et al., 2021).

Contributions and Future Directions

Findings underscore the central role of touch in the mutual regulation process and during perturbed interactions, both at the micro- and macro-levels. Our study uniquely contributes to the literature as it is the first to examine mothers' and infants' concurrent use of touch during episodes of crying. It is also the first to investigate tactile synchrony in a manner that accounts for infants' own use of touch. The limited prior research on tactile synchrony within mother-

infant dyads (i.e., Feldman et al. 2010) examined mothers', and not infants', touching behaviours during shared mother-infant gaze. Unidirectional examinations alike are inadequate given infants' capacity to effectively utilize and respond to touch as well as the inherent mutuality of touch during dyadic interactions (Ciaunica & Fotopoulou, 2017; Crucianelli & Filippetti, 2020). Consequently, previous investigations of tactile synchrony have been incomplete and perhaps more reflective of mothers' tendencies to use touch during moments of shared attention. By examining both maternal *and* infant touch, we captured the reciprocal nature of the tactile modality and measured tactile synchrony in a manner that is most consistent with other, more well-established forms of interpersonal synchrony (e.g., physiological synchrony; Davis et al, 2018). A universally agreed-upon definition and method of analysis for interpersonal synchrony of touch and other behavioural, emotional, physiological, and neurological constructs are needed to facilitate cross-study comparisons (Mayo & Gordon, 2020).

Future research may also expand on the limitations of the current study. Consistent with previous research pertaining to infancy and vulnerable groups, the present study was limited in generalizability due to the small sample size and inclusion of only one age group. Larger sample sizes of mother-infant dyads and longitudinal investigations beginning from birth and across the first months of life are necessary to determine the developmental trajectories of crying and touch patterns among typically developing and at-risk dyads. By focusing primarily on maternal and infant touch, we were unable to draw conclusions about the coordination of other communicative behaviours during instances of infant crying. Nonetheless, our emphasis on tactile communication is supported by the lack of research pertaining to this modality. Finally, future studies are warranted to consider the interactive patterns that emerge between infants and their other primary caregivers, who may or may not present with their own risk of psychopathology.

This line of research would shed light on the potential protective factors for at-risk infants and add to our understanding about the progression of infants' communication and regulation strategies (Masten et al., 2021).

Conclusions

The design and results from the present study enrich our limited knowledge about the dynamic interplay of maternal and infant touch. Although more research is required to replicate the current set of findings, results suggest that relative to other forms of synchrony, the trajectory of tactile synchrony may be more optimal than once considered among depressed dyads. Since the tactile modality represents mothers' and infants' very first channel of reciprocal social exchange (Mantel et al. 2021; Quintero & De Jaegher, 2020), dyads may be better at using touch to regulate and repair disruptions in their interactions that are marked by infant crying. Regarding affectionate touching behaviours, however, deviations from typical maternal and infant interactions were identified among depressed dyads following maternal unavailability and during periods of infant crying. Such deviations may mark important developmental differences in the social-emotional competence of at-risk children (Moore et al., 2001). Affectionate touch has recently been found to facilitate other forms of synchrony in mother-infant dyads (Carozza & Leong, 2021; Della Longa et al., 2020; Hoehl et al., 2021). Therefore, affectionate touching behaviours within the context of infant crying represent a meaningful target for the development and provision of preventative intervention programs (Field, 2014; Mantis et al., 2019; Oberlander, 2005). Taken together, findings support a movement toward more comprehensive and complete examinations of the tactile modality among both typically developing and at-risk dyads.

Table 1. *Behavioural observational coding systems and adaptations for maternal and infant touch in the present study.*

	Coding System		
	Caregiver-Infant Touch Scale (CITS); Stack et al., 1996; Jean et al,, 2009	**Infant Touch Scale (ITS);** Moszkowski & Stack, 2007	
Global Touch Category	***Specific Touch Category***		***Brief Description***
Affectionate	1.Static	1.Static	Touch without movement.
	2.Stroke/Caress/Rub/ Massage	2.Stroke/Caress/Rub/Wipe	Lateral soft and gentle movements or rubbing motion involving strong back and forth or circular movements.
	3.Pat/Tap	3.Pat/Tap	Quick up and down motions using either palm or fingertips.
Playful	4.Grasp/Squeeze/ Pinch	4.Grasp/Clutch/Clasp	All or some of fingers are curled around a stimulus, includes firmer hold or grip.
	5.Poke/Prod/Tickle/Fingerwalk/Push	5.Poke/Prod/Manipulate/ Finger/Scrumble	Involves small repetitive movements, generally in a random fashion. Includes handling or extending finger(s).
	6. Pull/Lift/ Clap/Extension	6. Pull/Lift/Clap/Push	Pulling or pressing of stimulus; striking hands against each other; raising a stimulus higher than its original position.
Remaining		7.Mouthing	Touch through lips, or when infant's hand makes contact with their mouth region.
	7.Shake/Wiggle		Moving part of the infant in short quick motions from side-to-side or up and down.
	8.Other		Any other type of touch that cannot be classified in any of the above categories.

Note. Touch categories pertain to tactile contact via the hands. Shake/Wiggle, Other, and Mouthing, were not placed into the "affectionate" or "playful" global categories, as they are not shared by the CITS and ITS. However, "total maternal touch" and "total infant touch" (as referenced throughout the text) were obtained by summing the values corresponding to all specific/individual types of touch within the CITS and ITS, respectively (including the "remaining" categories).

Chapter 7: General Discussion

The present dissertation comprised a series of three innovative studies, each designed to examine qualitative and quantitative aspects of parents' and infants' touching behaviours, including the synchrony of their touch. Together, these studies elucidate our limited understanding about the development of parents' and infants' use of touch within and across varying types of parent-infant interactions over time, in both typically developing and at-risk populations.

Study 1 examined the interrelation of mothers' and infants' touching behaviours longitudinally at 1-, 3-, 5-, 7-, and 9-months postpartum and within two typical mother-infant interaction contexts, including a proximal exchange whereby infants were seated on their mothers' laps (i.e., lap context) and a playful exchange whereby dyads engaged in a free play on the floor with age-appropriate toys (i.e., floor context). Findings revealed that patterns of tactile synchrony varied over time and were especially tied to rudimentary types of touch that possess soothing and regulatory properties (e.g., static, stroke). At 1-month postpartum, dyads were more likely to display behavioural matching, which entailed the simultaneous use of the same type of touching behaviour. However, as infants aged and acquired more advanced motor skills, dyads transitioned to a more complex form of synchrony, which entailed the parallel use of complementary types of touch (e.g., maternal pull/lift corresponded with infant grasp; maternal stroke/caress corresponded with infant static touch). Results from this study demonstrated infants' ability to actively contribute to their typical mother-infant interactions through touch, starting as early as 1-month postpartum, and revealed how mother-infant touch patterns naturally progress across the first 9-months of life. To our knowledge, Study 1 is the first of its kind, as no

other study has extensively examined the synchrony of mothers' and infants' touching behaviours longitudinally across the first 9-months of life and across two normative contexts.

Study 2 expanded on Study 1 by examining the development of infant touch and mother-infant tactile synchrony *starting from birth* and across two kinds of *perturbed* interaction contexts. That is, newborns', mothers', and fathers' touching behaviours were explored during their very first social exchange occurring just moments after birth, and in relation to more global behaviours characteristic of the immediate postpartum period; namely, infant crying, mothers' displays of pain, and breastfeeding. Three-months later, the touching behaviours of these same infants and mothers were examined following a period of maternal emotional unavailability (i.e., SF). Findings revealed newborn infants displayed touch throughout the large majority of the first hour after birth (at significantly higher rates than their mothers and fathers) and were predominantly reliant on rudimentary types of touch (e.g., static, mouthing, flexing, fisting). Interestingly, higher levels of maternal touch such as holding were associated with lower levels of infant crying, and higher levels of newborn static touch were associated with higher levels of breastfeeding; both associations revealed the soothing and regulatory role of touch at this time. Newborn touch immediately after birth positively predicted total infant touch after, but not before, the SF 3-months later. A significant inverse pattern of mother-infant touch synchrony (i.e., opposing yet corresponding changes in maternal and infant touch) was found across these same contexts over time, reflecting a reciprocal, turn-taking dynamic likely produced by mothers' attempts to soothe and regulate their infants following periods of stress (physiological stress following birth, social stress following SF). Such findings supported our previous research on maternal touch by further revealing the parallel nature of the post-birth and post-SF contexts (Mercuri et al., 2019). Study 2 also significantly contributed to the extant literature by being the

first to examine newborn touch in the immediate postpartum period, as well as the first to explore the development of mother-infant tactile synchrony across perturbed interactions from birth to 3-months postpartum.

Building on the findings of Study 2, Study 3 examined maternal and infant touch and synchrony across varying forms of perturbed mother-infant interactions and specifically at 4-months postpartum. Given the associations between maternal touch and infant crying in Study 2, as well as the findings yielded within the context of maternal emotional unavailability, Study 3 explored mothers' and infants' simultaneous touch patterns during instances of infant crying following maternal emotional *and physical* (Separation procedure; Field et al., 1986) unavailability. In contrast to Studies 1 and 2, which both focused on typically developing dyads, Study 3 investigated the touching behaviours of dyads at-risk via maternal depressive symptomatology. Results revealed that mothers and infants, including those in the at-risk (i.e., higher levels of depression) group, displayed a positive pattern of tactile synchrony during infant crying episodes, characterized by corresponding increases in mothers' and infants' displays of touch. Dyads in the at-risk group displayed significantly less affectionate touch during instances of infant crying. Accordingly, more depressive symptoms were associated with less maternal and infant touch, as well as less infant crying. As such, postpartum depression appears to influence infants' reactivity to social stressors and thus influences specific properties of maternal and infant touch. The limited amount of affectionate touch used by mothers and infants at-risk via high levels of maternal depressive symptomatology suggested that these dyads may have impaired regulatory abilities or may simply need less touch to recover from brief interactive disruptions. By examining maternal and infant touch in relation to infant crying, Study 3

deepened our understanding of how and why depressive symptoms can alter the course of early mother-infant interactions.

Common Threads and Highlights across the Studies

Key commonalities can be drawn across the results from each of the present studies to enhance our knowledge of touch and infant development. Studies 1 and 2 illustrated the impressive range of touching behaviours displayed by infants within the first hour to the first month of life, formally defined as the neonatal period (i.e., initial 28 days of life; World Health Organization, 2006). Neonates in both studies displayed high levels of rudimentary types of touching behaviours such as static touch, stroking, mouthing, flexing, fisting, patting, and grasping during their parent-infant interactions. Studies 1 and 2 thus demonstrated neonates' preparedness to utilize and sustain a range of specific touching behaviours which go well-beyond mere tactile contact. Congruently, results from Studies 1 and 2 illustrated that these same rudimentary types of touch are foundational to the development of mother-infant tactile synchrony.

Previous research has demonstrated that in general, interpersonal synchrony among mother-infant dyads emerges at 3- or 4-months postpartum (Bell, 2020; Feldman, 2012; Northrup & Iverson, 2020). While all three of the current studies supported the presence of tactile synchrony at 3- and 4-months postpartum, Studies 1 and 2 provided initial evidence for its emergence in the neonatal period, including in the first hour of life. These findings, combined with the consensus that touch is the basis of all other forms of communication (Heller, 2014; Hertenstein et al., 2006), suggest that tactile synchrony may be the most primal form of interpersonal synchrony. The potentially primitive nature of tactile synchrony may help explain why mothers and infants in the depressed group of Study 3 demonstrated a strong positive

pattern of tactile synchrony comparable to that of the non-depressed group. That is, given that tactile synchrony appears to emerge immediately after birth (Study 1), it is possible that the dyad's ability to establish synchrony through touch may be strengthened across their interactions over time, rendering tactile synchrony less susceptible to the effects of maternal depression or more optimal among depressed dyads relative to other forms of synchrony.

Yet, it is also important to note that while the present studies collectively demonstrated mothers' and infants' ability to establish tactile synchrony, the particular pattern or type of tactile synchrony exhibited was strongly tied to the interaction context and the precise period of development. Study 1 revealed that within the context of typical, including proximal and playful, interactions from 1- to 9-months postpartum, mothers and infants displayed a positive pattern of tactile synchrony which reflected corresponding increases in either the same or complementary types of touch. Study 2 indicated that, following the natural perturbation of birth to the experimental perturbation of the SF 3-months later, mothers and infants demonstrated an inverse pattern of tactile synchrony in their overall use of touch that reflected a reciprocal, turn-taking dynamic. In Study 3, mothers and their 4-month-old infants displayed a positive pattern of tactile synchrony during the brief, micro-level perturbation of infant crying, which entailed coordinated increases in their overall use of touch. These findings reveal that tactile synchrony is a dynamic and fluid process bound to unfold differently according to contextual factors and support prior research indicating that touch is context dependent (Hertenstein, 2002; Stack, 2010).

Taken together, the present studies make significant advancements to the fields of touch, synchrony, and development. In addition to highlighting the value of considering a breadth of contexts, ages, and populations using both longitudinal and cross-sectional research designs, results from the three studies of this dissertation support the movement toward

bidirectional investigations of touch which capture simultaneous changes in *both* maternal and infant touch (Mantis et al., 2014; Mantis & Stack, 2018). Importantly, the present studies add to the few prior bidirectional investigations of touch (Mantis & Stack, 2018; Mantis et al., 2014) by describing the interconnectedness of the precise types and amounts of mothers' and infants' respective touching behaviours, thus demonstrating *how* they both use touch to actively engage in shaping and co-regulating their interactions. As such, the present set of results are also consistent with theoretical models of development which regard to mothers and their infants as an integrated, coupled system (Beebe et al., 2016; Fogel, 2009) and which emphasize the importance of equally capturing how both members of the dyad contribute to their interactions (DiCorcia & Tronick, 2011).The reliance on unidirectional investigations of touch, which focus on *either* maternal or infant touch, represents one of the most noteworthy limitations within the extant literature to date. Regarding synchrony, there have been few studies that have assessed the tactile modality; while these studies have advanced our knowledge on early interpersonal dynamics, these studies have neglected infant touch (e.g., Feldman et al., 2010). Such an approach has been insufficient since touch is an inherently social sense and the tactile modality is a shared form of communication between infants and their caregivers (Ciaunica & Fotopoulou, 2017; Crucianelli & Filippetti, 2020; Florita, 2021; Morrison et al., 2010). Therefore, it is only through a bidirectional approach that the synchrony and coordination of maternal and infant touching behaviours can be truly observed.

To our knowledge, we provided the first set of complete examinations of tactile synchrony to date. We also acquired a deeper understanding of tactile synchrony by examining multiple parameters of the tactile modality (i.e., various types of touching behaviours, duration of each type of touch), thus accounting for the multidimensional nature of touch. In doing so, we

addressed another noteworthy limitation in the extant literature; despite being complex and multifaceted, touch has often been examined and described as a simplistic or a one-dimensional construct (Hertenstein, 2002; Field, 2010; Stack & Jean, 2011; Mercuri et al., 2019). As such, the current dissertation took essential steps and filled substantial gaps in the existing research. The findings yielded from all three studies meaningfully add to our understanding about how parents and infants use touch to jointly contribute to their dynamic interactions, and by extension, the parent-infant relationship.

Theoretical and Practical Implications

The current research supports yet also expands upon theoretical models of development. Specifically, findings from all three studies support the dynamic systems perspective by confirming that both members of the mother-infant dyad actively contribute to their social interactions and are mutually sensitive and responsive to the behavioural and emotional changes displayed by their partner (Beebe et al., 2016; Field, 2014; Fogel, 2009). The present research likewise supports the Mutual Regulation Model (Tronick, 1989, Tronick & Weinberg, 1997) by demonstrating that mothers and infants form an integrated, dyadic system and co-construct their interactions through a collective exchange of communicative signals (Tronick, 1989; Tronick & Weinberg, 1997). In particular, our findings demonstrated that mothers and infants use touch to mutually regulate following the physiological stress of labor and delivery (Study 2) and the social stress of maternal emotional (Studies 2 and 3) and physical (Study 3) unavailability, during instances of infant crying (Studies 2 and 3), and throughout typical and playful interactions (Study 1). Accordingly, the present research underscores touch as a critical means of soothing and calming infants during normative and perturbed (micro- and macro-level) mother-

infant interactions. Thus, our findings not only demonstrate that touch is a central component of the mutual regulation process, but also exemplify the extent to which this holds true.

Moreover, the present research is in accordance with transactional models of development which posit that mother-infant interactions can serve as a framework that either fosters healthy development or transmits risk (Sameroff, 2009). The current dissertation emphasizes the role of maternal and infant touch during early interactions in scaffolding infants' communicative and emotion regulation skills, which are essential to healthy development. Results from Study 3 suggested that maternal postpartum depression may be one means through which risk may be transferred to infants, given that mother-infant dyads with high levels of depressive symptomatology displayed lower rates of affectionate touching behaviours during infant crying episodes. As mentioned above, this deviation from typical touch patterns may reflect impaired regulatory abilities, including mothers' and infants' ability to repair brief disruptions in their interactions using tactile behaviours and perhaps other communicative modalities as well.

Consequently, affectionate touching behaviours may represent important targets for screening and early touch intervention programs for depressed mothers and their infants, as well as other at-risk populations. Indeed, affectionate (i.e., affective) touch has recently garnered increased attention in the extant literature due to findings revealing its role in regulating infants' interoceptive and exteroceptive states (Crucianelli & Filippetti, 2020; Busuito et al., 2019). Additionally, recent evidence suggests that affectionate touch accounts for the pleasurable and rewarding properties of touch (Cruciani et al., 2021), and facilitates behavioural, neural, and physiological forms of synchrony (Carozza & Leong, 2021; Goldstein et al., 2017; Hoehl et al., 2021) that promote secure attachment (Isabella & Belsky, 1991; Feldman, 2017; Mantel et al.,

2021) and positive long-term childhood outcomes (Ambrose & Menna, 2013). Focusing on the use of these specific behaviours during the context of perturbed interactions, and not just touch in general, would also be particularly useful given that depressed dyads were not found to use affectionate touch differently than non-depressed dyads prior to their perturbed interactions.

Findings from the present studies may be translated into clinical interventions and integrated with existing evidence-based intervention programs. For example, Mother-Baby Interaction (MBI) Therapy (Horowitz et al., 2019) and specialized Cognitive Behavioral Therapy (CBT; Ntow et al., 2021) have been designed for infants and mothers with postpartum depression (Ntow et al., 2021). Our findings compliment these recently developed programs as they aim to support mothers' sensitive, responsive, and contingent interactions with their infants (Horowitz et al., 2019) and appear to simultaneously reduce infants' withdrawn behavior (Ntow et al., 2021). These programs would be strengthened by the incorporation of behavioural interventions aimed at teaching mothers (and caregivers in general) how to utilize touch that is aptly in accordance with the age of their infant and the nature of the interactive context. Such interventions may include the provision of concrete skills pertaining to using the tactile modality to repair interactive disruptions and scaffold the development of infants' abilities to regulate their own emotions through touch. Additionally, both typically developing and at-risk families would benefit from receiving psychoeducation in the prenatal period on the importance of tactile contact, and more broadly, the utility of engaging in regular social exchanges. The dissemination of this knowledge would promote early care practices that ultimately foster optimal infant development and well-being.

Future Directions and Limitations

To support the applied implications of the present research, future studies should further explore how and whether at-risk populations demonstrate atypical or differing patterns regarding affectionate (and other) touching behaviours, and how such patterns may compare to visual and vocal communicative modalities. To further advance our understanding about the development of touch, future research should also expand on the present research by employing additional longitudinal investigations of touch patterns that span across the latter half of infancy (i.e., beyond 9-months), toddlerhood, and childhood. Studies of this nature, as well as statistical approaches that are designed to capture dyadic relationships and acknowledge interdependence between parents and infants (i.e., Actor-Partner Independence Model), would enhance our ability to understand the evolution of dynamic parent-infant touch patterns. It would also be important to consider how touch patterns, including those displayed immediately after birth, directly relate to longer-term outcomes relating to children's psychological, social, and emotional well-being. This represents a limitation of the present research, as none of the current studies examined touch in relation to long-term indicators of health and well-being. An additional limitation of the present research was our more minimal focus on fathers' touching behaviours. While Study 2 examined paternal touch in the immediate postpartum period and in relation to maternal and infant touch during the immediate postpartum period, the synchrony of fathers' and infants' touch was not explored. The literature would benefit from bidirectional and longitudinal examinations of paternal and infant touch, especially in light of the scarce research on fathers within the field of touch and, while growing, the developmental research altogether. Congruently, future studies would benefit from sampling more diverse populations and including more varied family structures to enhance generalizability and broaden our knowledge of the tactile modality within the context of caregiver-infant interactions. Finally, based on our findings

demonstrating the pervasiveness of touch across various kinds of contexts, future research should further examine more diverse contexts, in addition to normative and perturbed interactions, especially those with naturalistic qualities and those that occur outside of a laboratory setting.

Conclusions

Beginning from birth and throughout the first 9-months of life, touch is a fundamental part of parents' and infants' lives. Infants, as soon as they emerge from the womb, have a key role in shaping their interactions with their parents and demonstrate a fundamental ability to form a synchronous dialogue through touch. The results from this dissertation contribute greatly to the scant literature on touch and make significant advancements to our understanding of the tactile modality. Findings enrich our scant knowledge of touch and reveal it as a vital channel between parents and their infants across typical and perturbed contexts, including those that are brief or more prolonged. Individually and collectively, the design and results from the present studies offer direct implications for early care practices as well as for the design and provision of parenting intervention programs.

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Appendix A

Consent Form for Study 1

The Development of Communicative Behavior in Infancy

INFORMED CONSENT DOCUMENT
PLEASE READ THIS CAREFULLY BEFORE SIGNING

You and your baby are being asked to participate in an in-depth research study on the process of social development in early infancy. Although a good deal of research has already been done in this area, a lot is still unknown. One of the missing pieces in our knowledge is how individual infants grow and change. We know the basic stages of social development -- such things as when babies learn to communicate their feelings by crying or smiling, when they learn to use gesture and expressions and when they learn to start using words and language.

What is lacking is knowledge about how these changes occur. We want to find out how individual baby learns to control his or her behavior for the purpose of social play and communication. We can only to this by watching the subtle and small changes that take place over time when the baby is observed repeatedly in the same social situation.

The study in which we are asking you to participate is unique in the history of child development research, and it requires as a unique commitment on your part. Only a handful of babies have been observed intensively for an intended period. Those studies were done 10 or more years ago, long before we had powerful tools of behavior analysis embodied in the videotape and computer of today. We are hoping you will have the time, energy and motivation to join us in this pioneering research effort.

We want to be as clear as possible about what we will be expecting from your participation in this research project. Please read carefully each of the procedures listed below, and ask us any questions that you may have about them, First, we'll describe each procedures, and then we'll explain why it is used and what the potential risks are to you and your baby.

(1) Laboratory Playroom Observations: This is the core part of the research study. We will be asking you to come to our laboratory once each week, at a mutually convenient time, to spend about 30 minutes interacting spontaneously with your baby in a comfortable playroom setting. We will try to be flexible in the scheduling of the visits. Although we prefer a regular visitation schedule, we can adjust for illness, doctor's visits, other conflicting commitments, etc. So long as you try to maintain a regular schedule, there is no problem skipping weeks occasionally for vacations, etc. We hope these visits become an enjoyable part of your week, a time for you and you baby to spend some special moments together. During this time you will interact with your baby while he / she is on your lap, on the floor, or at a table. The particular setting will depend on your baby's age.

(2) Observations in your home: Although the core of our research is the laboratory playroom observations, it is important for all research studies on human development to be generalizable beyond the scope of the laboratory. For this reason, we feel it is important to test the validity of our laboratory observations against you baby's normal behavior at home. In order to do this, we plan to come to your home beginning when your baby is three months of age, and for every three months after that. We will stay for a period of about 2 hours on each visits, and

we would like to come at a time when all of the family members are present in order to see how your baby responds socially to his/her father and sibling, as well as to you. If this is not possible, we can come at anytime when its convenient for you.

Because of the complexity of social interaction, we will be videotaping your baby in the home, in the same way we did in the laboratory playroom. Although it is hard to "act natural" with several extra people, trailing video cameras and wires around your home, we ask you to pretend we're not there.

None of these procedure are experimental. They have all been used in our research with other families in the Lafayette/West Lafayette area. What is different is that we wish to have your collaboration over a longer term than most research studies require. We have found that families enjoy participation in our research studies. Since we are interested in your baby's natural and spontaneous social behavior, we do not do any invasive or experimental procedures. Your baby is likely to become familiar with our playroom and with our staff, and will probably look forward to his/her visits here. Our standardized assessments are often interesting and challenging to babies, and informative for parents.

Your participation in this research study is protected by standard confidentiality guidelines used in most research done with human subjects in this country. This means that all identifying information about you and your family is kept in a locked file under the supervision of the project director, Dr. Alan Fogel. Videotapes and standardized assessments will only be identified by a number, and the correspondence between the number and your name is known only by the project staff. Your name of your baby's name will not be released in any publication or presentation of these results to the public.

Due to extensive commitment we are requesting, and to cover any inconveniences and transportations costs, we will offer you a small honorarium of $300.00 per year, $150 payable at the end of each six months of complete participation.

If you have any other questions, now or at anytime during the period of the research study, feel free to contact Dr. Alan Fogel, Department of Child Development and Family Studies, Purdue University, 494-5744

_____ _____

Parent signature Date

Appendix B

Consent Form for Study 2

ID _____

Ricerca dal titolo:

Il ruolo del tocco materno nell'interazione madre-bambino alla nascita e a tre mesi di vita

CONSENSO INFORMATO ALLA RICERCA

I sottoscritti:
(Cognome, Nome della madre) _____

(Cognome, Nome del padre) _____

in qualità di genitori/legali rappresentanti di
(Cognome, Nome del bambino) _____

dichiarano

di aver letto la lettera informativa relativa allo studio in oggetto, e di essere stati informati in modo chiaro e comprensibile da _____, collaboratore del Dott. Montirosso (Responsabile Scientifico dello Studio), sulle finalità della ricerca in oggetto e sulle modalità attraverso le quali verrà effettuata, nonché di avere avuto modo di chiedere ogni delucidazione.

Accettano

volontariamente di prendere parte alla ricerca e inoltre

Autorizzano

volontariamente che il/la proprio/a figlio/a
(Cognome, Nome in stampatello) _____

prenda parte a questo studio.

Data _____ Firma leggibile (della madre) _____

Data _____ Firma leggibile (del padre) _____

L'informatore (Cognome e Nome) _____

Data _____ Firma dell'informatore _____

Appendix C

Consent Form for Study 3

Informed Consent
Preventing Depression in Infants

We are doing a study on how being depressed may affect your baby, the ways to reduce depression in mothers, and how to prevent it in infants. During your pregnancy, after your baby is born and during your baby's first two years of life, we will interview you and test your baby. The tests are strictly for our study and will be confidential.

During Pregnancy

If you agree to be in the study, between your 3rd and 9th month of pregnancy you will be asked to complete questions on alcohol and smoking and your general health during pregnancy. In addition, we will ask you some questions regarding your feelings of depression, anxiety, stress, anger, daily hassles and your attitudes and knowledge about being pregnant and raising children. These will take between 1-2 hours to complete. We will ask for a urine sample to look at different hormones. You will be asked if we can observe two of your ultrasounds and/or if you are interested in having your significant other or family member learn a pregnancy massage and provide twice weekly 20-minute massages during pregnancy. The massage may be a moderate or light pressure or you may be in a group that receives no massage. If you are in a massage group, and if you prefer, massage therapists can conduct your massages at the U.M. Touch Research Institutes. Ultrasound sessions will take place in the prenatal clinic during your second and third trimesters of pregnancy and will last approximately 25-50 minutes. In order to record how your baby moves inside you. Head, foot or hand massage at the ultrasound clinic will last 3 to 5 minutes and we will watch your baby for 4 minutes during the ultrasound to see how he/she moves.

After you give birth

Shortly after birth, a psychologist will test your baby's alertness, behaviour and physical activity and we will ask you how you feel. We will also videotape your baby and record the baby's heart rate. Heart rate will be recorded at the same time we collect brain wave information through electrodes (little round stickers) placed on your baby's chest. We will take recordings of you and your baby's brain waves to see if they are affected by your moods. For the brain wave test we will place a few sensors on your baby's head and a cap on your head. We will also place 3 sensors on your chest area, arm, or neck to record heart rate. This will not cause any discomfort. There are no risks to these procedures. These recording only take a few minutes. We will also record you and your baby during a feeding, ask you questions about breast feeding and we will ask for a sample of you and your baby's urine. This visit will take approximately 2-2½ hours. We may also show you how to massage your baby and ask you to do a bedtime massage every night.

During the first 6 months

Once a month, for the first 6-months of your baby's life, we will ask you to come back to our video lab where we will videotape you while you and your baby play together for about 5 minutes. One video camera will be focused on your baby's face and record your baby's

expressions and another will be focused on your face and record your expressions. We will also videotape your baby's responses to a Raggedy Ann doll's face (at the 4-month visit), to another baby's face and your baby's own face in a mirror (at 5 months), and to an object (e.g., a star versus a round-shaped object at 6 months). We will erase the videotapes after we finish analyzing them. We will ask for another urine sample from you and your baby at one of these visits and ask you some questions about stress. When your baby is 6 months we will give him/her a developmental test and a physical examination.

We will pay $20.00 for each visit. If we find any medical problems we will refer you to a doctor, your records and results will be given a number instead of your name and will be kept confidential to the extent permitted by law. If you decide to take part in the study with your baby, we will ask you for permission to review your medical records at delivery and your baby's medical records at birth. The results of this study will be reported as group results to protect your identity. Your records may also be bound by the same provisions of confidentiality. The Department of Health and Human Services (DHHS) may review these research records.

Your participation is voluntary and if you do not want to be in the study, you can leave at any time and it will not hurt your treatment. Feel free to ask questions at any time. For questions regarding this study contact Dr. Tiffany Field at 305-243-6781. You will receive a copy of this consent form for your records. If you have any questions about your rights as a research subject you may contact Maria Arnold, IRB Director, University of Miami at 305-243-3195.

_____ _____

Signature of Mother Date

Appendix D

Coding Criteria for Behavioural Observation Coding Systems

Table 1D. *Brief coding criteria for the Caregiver-Infant Touch Scale (CITS) (Stack et al., 1996; Jean et al., 2009).*

Touching behaviour	**Brief description**
Static	Touch without movement
Stroke/Caress/Rub/Massage	Lateral soft and gentle movements or rubbing motion involving strong back and forth or circular movements
Pat/Tap	Quick up and down motions using either palm or fingertips
Squeeze/Pinch/Grasp	Taking hold of infant's body or limb, or part of infant's body or limb, using a firmer hold or grip
Tickle/Finger Walk/Prod/Poke/Push	Usually involves bent finger(s) and often repetitive small movements
Shake/Wiggle	Moving part of the infant in short quick motions from side-to-side or up and down
Pull/Lift/Extension/Clap	Stretching or raising infant's limb away from infant's body
Other	Any other type of touch that cannot be classified in any of the other 7 categories. Typically includes kissing, blowing, and rocking

Table 2D. *Brief coding criteria for the Caregiver-Infant Touch Scale - Adapted (CITS - Adapted) (Mercuri et al., 2019).*

Touching behaviour	**Brief description**
Static	Touch without movement
Stroke/Caress	Lateral soft and gentle movements
Massage/Rub	Rubbing motion involving strong back and forth or circular movements
Holding	Taking hold of infant's body or limb, or part of infant's body or limb
Kissing	Touch through lips
Palmar Grasp Reflex	Finger(s) enclosed within infant's hand
Utilitarian/Instrumental	Includes adjusting infant's clothing, wiping infant's mouth, moving infant's positioning, etc.
Rocking	Moving of infant's body in back and forth movements. Coded for mothers only
Blowing	Expelling air through pursed lips toward infant. Coded for fathers only.
Other	Any other type of touch that cannot be classified in any of the above categories.

Table 3D. *Brief coding criteria for the Infant Touch Scale (ITS) (Moszkowski & Stack, 2007)*.

Touching behaviour	**Brief description**
Static	Touch without movement
Rub/Caress/Wipe/Stroke	Lateral soft and gentle movements or rubbing motion involving strong back and forth or circular movements
Grasping/Clutching/Clasping	All or some of infant's fingers are curled around a stimulus
Manipulating/Fingering/Scrumble/Poke/Prod	The infant runs the tip of his/her finger(s) over a surface, generally in a random fashion. Includes handling, flexing, or extending finger(s), sometimes in a repetitive manner
Mouthing	Infant's hand comes into contact with his or her mouth, including the lips and outside of mouth
Tap/Pat	Quick up and down motions using either palm or fingertips
Pull/Push/Clap/Lift	Pulling or pressing all or part of a stimulus; striking hands against each other; raising a stimulus higher than its original position

Table 4D. *Brief coding criteria for the Infant Touch Scale (ITS) - Adapted (Mercuri et al., 2020b).*

Touching behaviour	**Brief description**
Static	Touch without movement
Grasping/Clasping	All or some of infant's fingers are curled around a stimulus; includes curled fingertips and palmar grasp
Rub/Wipe	Lateral movements or rubbing motion involving multiple fingertips, palm, or back of hand
Mouthing/Suckling	Infant's hand comes into contact with his or her mouth, including the lips and outside of mouth, or a stimulus such as surface of mother's body or blanket
Flexing/Fisting	Opening and closing of hands/fingers; hand positioned in fist
Tap/Pat	Quick up and down motions using either palm or fingertips
Other	Any other form of touch not represented in the above categories

Table 5D. *Brief coding criteria for the Behaviours in the Immediate Postpartum Period Scale (BIPPS) (Mercuri et al., 2020a).*

Behaviour	**Brief description**
Crying/Fusing	Infant crying, fussing, fretting, as indicated by negatively toned vocalizations and facial expressions such as grimacing
Feeding	Infant is breastfeeding or latching onto breast; mother is attempting to orient infant toward breast
Visible Displays of Maternal Pain	Mother demonstrates state of pain via distressed vocalizations, facial expressions (puckered lips, tightened facial muscles), and gestures (e.g., covers face with hand)

Note. Maternal pain (as captured by coding category 3) attributed to physical effects of labor and delivery, corresponding difficulty moving positions on hospital bed, and medical procedures following episiotomy/perineotomy.