



PAPER

Touch attenuates infants' physiological reactivity to stress

Ruth Feldman, Magi Singer and Orna Zagoory

*Department of Psychology and the Gonda Brain Sciences Center, Bar-Ilan University, Israel***Abstract**

Animal studies demonstrate that maternal touch and contact regulate infant stress, and handling during periods of maternal deprivation attenuates the stress response. To measure the effects of touch on infant stress reactivity during simulated maternal deprivation, 53 dyads were tested in two paradigms: still-face (SF) and still-face with maternal touch (SF+T). Maternal and infant cortisol levels were sampled at baseline, reactivity, and recovery and mother's and infant's cardiac vagal tone were measured during the free play, still-face, and reunion episodes of the procedure. Cortisol reactivity was higher among infants in the SF condition and while cortisol decreased at recovery for infants in the SF+T, it further increased for those in the SF. Vagal tone showed a greater suppression when SF was not accompanied by maternal touch. Touch synchrony during free play was associated with higher infant vagal tone, whereas touch asynchrony – maternal tactile stimulation while the infant gaze averts – correlated with higher maternal and infant cortisol. In humans, as in mammals, the provision of touch during moments of maternal unavailability reduces infants' physiological reactivity to stress.

Introduction

Animal studies indicate that maternal touch and contact carry a life-long organizing effect on the infant's stress management systems and function to regulate the stress response (Champagne, 2008; Hofer, 1995; Meaney, 2001). Early maternal separation has been linked with long-term disruptions to the HPA-axis stress regulating system, resulting in increased baseline cortisol, altered patterns of cortisol reactivity, and disrupted recovery of the system following stress (Levine, 2005). On the other hand, touch and handling during periods of maternal deprivation were shown to buffer the negative effects of stress on the pup's physiological reactivity (Weller & Feldman, 2003). Much less research has examined whether touch during moments of maternal deprivation has a similar regulating effect on the stress response of the human infant.

The notion that touch during periods of maternal deprivation attenuates the effects of separation on the human infant's physiology is supported by research in premature infants. Prematurity provides a human model for the study of maternal deprivation, as mother and infant are separated immediately after birth, infants are placed in incubators, and full bodily contact is precluded during the post-birth period. Studies assessing the effects of skin-to-skin contact on the development of premature infants demonstrated that both stress hormones (Weller, Rozin, Goldstein, Charpak, Ruiz-Pelaez, Figueroa de

Calume, Charpak & Sack, 2002) and autonomic reactivity (Feldman & Eidelman, 2003a; Gray, Watt & Blass, 2000) were more optimal in the treated infants as compared to matched controls. Similarly, a daily regime of massage therapy improved cortisol reactivity and heart rate in premature infants (Field, 1995; Field & Diego, 2008). Similar to the long-lasting effects of early contact during periods of maternal deprivation on the stress response of young mammals, the positive effects of skin-to-skin contact on children's cortisol response and autonomic reactivity were found to persist across the first 10 years of life (Feldman, 2009).

Maternal still-face (SF) – an experimental paradigm in which mother interacts freely with the infant, then refrains from social communication and maintains a 'still-face', and finally resumes play – has been extensively used to simulate the experience of 'maternal deprivation' and examine its effects on the child (for review: Adamson & Frick, 2003). The negative effects of the mother's momentary unavailability on the infant's affect and behavior have been well documented, including high negative arousal, social withdrawal, increased self-soothing behavior, and re-engagement attempts. It has also been shown that during re-engagement much of the infant's stress-related repertoire is still observed and this episode contains significantly more stress indicators than the initial free play (Weinberg & Tronick, 1996). In terms of its impact on infant physiology, the SF procedure has been shown

Address for correspondence: Ruth Feldman, Department of Psychology and the Gonda Brain Sciences Center, Bar-Ilan University, Ramat-Gan, Israel 52900; e-mail: feldman@mail.biu.ac.il

to increase both cortisol levels and heart rate in infants (Haley & Stansbury, 2003; Lewis & Ramsay, 2005), indicating that the procedure creates sufficient stress to elicit a multi-dimensional physiological stress response.

Several studies used a modification of the SF paradigm that includes maternal touch during the SF episode (SF+T) and examined the differential effects of touch versus no-touch conditions on infant behavior. Touch during maternal SF reduced the infant's distress and elicited less crying, negative arousal, self-soothing behavior, and gaze aversion as compared to the standard SF (Stack & Muir, 1992). It has been suggested that during moments of maternal unavailability, touch functions to uphold the affective communication when other communicative channels are blocked (Jean & Stack, 2008). Whether or not this tactile continuity also attenuates the infant's physiological reactivity has not been examined. Such findings may suggest that the breach in social communication leading to physiological and emotional distress may be somewhat ameliorated by the continuation of tactile contact.

In addition to the momentary effects of touch on the stress response, maternal touch is a central determinant of the mother–infant communication system and carries a long-term impact on infant growth and development. Maternal affectionate touch in the postpartum, a behavior akin to the licking-and-grooming of mammals, has been associated with higher oxytocin whereas more intrusive types of stimulatory or functional touch have been correlated with higher maternal cortisol (Feldman, Weller, Zagoory-Sharon & Levine, 2007; Fleming, O'Day & Kraemer, 1999). Frequent maternal affectionate touch in the postpartum is related to higher infant baseline vagal tone (Feldman & Eidelman, 2007) and contributes to neurobehavioral, cognitive and social-emotional growth (Feldman & Eidelman, 2003b, 2004). Touch synchrony – the matching of maternal affectionate touch with mother and child's mutual gaze – has been shown to predict more optimal attachment behaviors, better regulation of negative arousal, and lower behavior problems (Feldman & Eidelman, 2004; Feldman, Granat & Gilboa-Schechtman, 2005). It is thus possible that more attuned and synchronous interactions that incorporate touch into the mutually regulating social system may facilitate more optimal autonomic and hormonal stress reactivity, whereas aversive touch that is not suited to the infant's communicative signals may be less conducive in downregulating physiological distress.

In light of the above, the present study examined the effects of maternal touch during moments of maternal unavailability on the infant's stress response. We expected that the SF+T condition would elicit significantly less physiological stress as expressed in lower cortisol reactivity and quicker cortisol recovery. We similarly expected that the SF+T condition would be associated with milder withdrawal of the vagal brake. According to Porges' (2003) polyvagal theory, vagal tone

(Vna) – the respiratory cycle in heart rate variability that is controlled by the regulatory parasympathetic system – reflects the mammalian capacity to mobilize sufficient energy to react to environmental challenges. Change in Vna from baseline to a stressful condition, the vagal brake, measures the organism's adaptive response to stress, and the degree of Vna suppression indexes the level of experienced stress (Porges, 1995). Studies have shown that infants' vagal tone withdraws in response to situational stress, including change from free play to the SF episode (Bazhenova, Plonskaia & Porges, 2001; Moore & Calkins, 2004), from free play to maternal separation during the 'strange situation' paradigm (Hill-Soderlund, Mills-Koonce, Propper, Calkins, Granger, Moore, Garipey & Cox, 2008), and in response to physical pain such as circumcision or heel-prick (Arditi, Feldman & Eidelman, 2006; Porter, Porges & Marshall, 1988), confirming that a decrease in Vna serves as an index for the magnitude of the stress response. In terms of the tactile component in the mother's general interactive style, based on research showing links between more positive and synchronous interactions during the free play episode with lower cortisol (Haley & Stansbury, 2003) and more optimal vagal regulation (Moore & Calkins, 2004), we expected that touch synchrony would be related to more adaptive physiological reactivity, whereas mysynchrony – the mother's stimulatory touch while the infant gaze averts – would correlate with more intense expressions of the stress response.

Method

Participants

Fifty-three mothers and their 6-month-old infants (25 boys, $M = 25.65$ weeks, $SD = 1.30$) participated. The original sample included 66 dyads but in 13 cases one or more cortisol assessment points were missing. Mothers were recruited on the 2nd post-birth day and were screened for symptoms of anxiety and depression in the postpartum and again at 6 months. Inclusion criteria were: singleton healthy infant, mother married or cohabitating with the infant's father, mother with at least high-school education, and mother over 21 years. Mothers were on average 28.9 years ($SD = 4.0$) and completed 14.6 ($SD = 2.3$) years of education.

Procedure

Mothers and infants arrived at the laboratory during the morning hours. Upon arrival, dyads were introduced to the lab and baseline salivary cortisol was assayed from mother and child. Mothers placed a roll of cotton in their own and the infant's mouth and both chewed on it for 1 minute until it became saturated and was placed in

a Salivette (Sarstedt, Rommelsdorf, Germany). Next, the infant was seated in an infant-seat mounted on a table and the mother sat facing him/her. Both mother and infant were connected to a dual-channel ECG monitor-IBI logger. Consistent with previous studies of vagal tone during the still-face paradigm (Bazhenova *et al.*, 2001; Moore & Calkins, 2004), Vna during free play was used as the basis for assessing infant autonomic response to the SF episode. Mothers were instructed to play freely with the infant for 3 minutes, maintain still-face with or without tactile contact for 2 minutes, and resume play for an additional 2 minutes. Interactions were videotaped for later coding from a control room using two cameras placed on adjacent walls and a split-screen video mixer. A tap on the window signaled the time to move to the next episode of the paradigm. Mothers were instructed to press the ECG monitor before moving to the next episode, and following the visit data were downloaded into a special computerized program. Twenty dyads were randomly selected to the SF+T condition and 33 to the non-touch SF condition. No instructions as to tactile contact during free play were provided. During the SF, mothers in the touch condition were instructed to keep tactile contact with the child in whichever way they chose while maintaining a still-face and refraining from all affective or vocal communication, whereas mothers in the no-touch condition were asked to maintain a still face and refrain from any tactile, vocal, or affective communication. After the SF paradigms, dyads remained in the lab for the following cortisol assessments. The second cortisol assay was taken 20 minutes after the SF procedure (reactivity), and 15 minutes after the reactivity assessment, the third cortisol sample was collected (recovery) in a similar way.

Measures

Cortisol

Salivettes were kept cooled until thawed before being centrifuged at 4°C at 1000 × g for 15 minutes. The samples were then stored at -20°C until assayed. Cortisol levels were assayed using a commercial ELISA kit (Assay Design, MI, USA). Measurements were performed according to the kit's instructions. Cortisol levels were calculated by using MatLab-7 according to the relevant standard curves. The intra-assay and inter-assay coefficients are less than 10.5 and 13.4%, respectively.

Vagal tone (Vna)

The vagal tone index was computed for mother and child for each episode of the paradigm: free play, still-face, and reunion. The Vna indexes the amplitude of Respiratory Sinus Arrhythmia from the heart period (inter-beat intervals in milliseconds) series by representing respiratory related heart period variability. Vna was

quantified using Porges' MXEdit software (Porges, 1985). The software samples the heart period into a time series and utilizes a third-order 21-point moving polynomial filter and a band pass filter with a frequency band related to the spontaneous respiratory cycle: between 0.24 and 1.04 Hz for infants and between 0.12 and 0.40 Hz for mothers. The Vna index is the natural logarithm of the variance of the detrended and filtered time series averaged over 15-second segments.

Coding

The free play episode was micro-coded offline for mother's and infant's behavior on a computerized system in .01 sec level for four categories of behavior, each containing a set of mutually exclusive codes. These included: Gaze (to partner, to object, joint attention, gaze aversion), Affect (positive, neutral, negative, withdrawn), Vocalizations (cry, fuss, yawn, positive vocalizations, e.g. cooing, babbling), and Touch (affectionate touch, e.g. caressing, hugging, kissing, loving pokes; functional/instrumental touch, e.g. whipping baby's mouth, fixing clothes; stimulatory touch, e.g. manipulating limbs, strong taps or massage; proprioceptive touch, e.g. moving infant to a sitting position). Inter-rater reliability, computed for 10 interactions (25%) averaged 94%, $kappa = .86$ (range = .80-.98). Consistent with previous research, two conditional probabilities were computed to index touch synchrony and myssynchrony. Touch Synchrony was the frequency of maternal affectionate touch while both mother and child were in social gaze ('to partner'). Touch Myssynchrony indicated the frequencies of maternal stimulatory and proprioceptive touch while the child showed gaze aversion. Such strong forms of touch when the infant signals a need for rest and regrouping indicate the mother's over-stimulatory behavior and low adaptation to the infant's level of engagement.

Infant behavior during the SF episode of the paradigm was coded for Gaze, Affect, Vocalization, Autonomic Response (e.g. breathing, wheezing, yawning), Motor Response (e.g. kicking, arching, moving in chair, attempts to get out of chair, limb movement, reaching) and Regulatory Behavior (e.g. thumb, pacifier, object manipulation, body manipulation). Inter-rater reliability computed for 10 interactions (25%) averaged 91%, $kappa = .82$ (range = .75-.96).

Results

Effects of touch on physiological stress reactivity

Cortisol

Descriptive statistics for infants' and mothers' cortisol levels at baseline, reactivity, and recovery and the *F* values for group differences appear in Table 1.

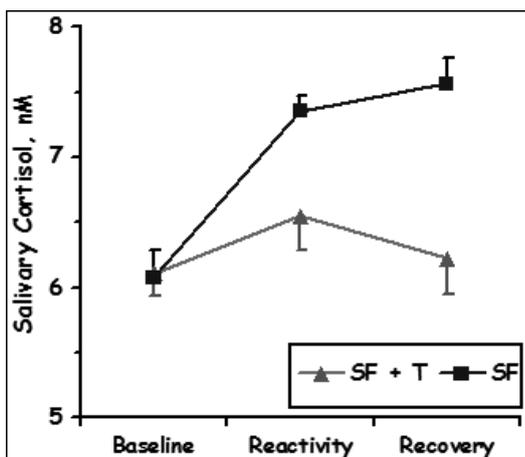
Table 1 Cortisol levels at baseline, reactivity, and recovery in infants and mothers in the still-face+touch and still-face conditions

	Still-Face+ Touch		Still-Face		<i>F</i>
	Mean	<i>SD</i>	Mean	<i>SD</i>	
<i>Infant</i>					
Baseline	6.11	1.54	6.08	1.29	.01
Reactivity	6.54	.93	7.35	1.87	4.96*
Recovery	6.22	1.45	7.56	2.02	5.29*
<i>Mother</i>					
Baseline	6.13	1.38	6.40	1.89	.29
Reactivity	6.02	1.23	6.08	1.55	.03
Recovery	6.19	1.38	6.28	1.41	.64

* $p < .05$.

A repeated measure ANOVA assessing change in infant cortisol across the three assessments showed change over time, Sphericity Assumed $F(df = 2) = 14.99$, $p < .000$, $\eta^2 = .12$, with the linear component being significant, Sphericity Assumed $F(df = 1) = 10.18$, $p = .002$, $\eta^2 = .16$. As seen (Table 1), no group differences were found in infants' cortisol level at baseline. However, lower cortisol levels were found at the second assessment for infants in the SF+T condition, pointing to a more attenuated physiological response. Finally, while cortisol decreased at recovery for the SF+T condition, it markedly increased for the non-touch SF condition, indicating continued stress during reunion (Figure 1).

No group differences between maternal cortisol levels were found across assessments and a repeated measure ANOVA showed no within-subject effect: Sphericity Assumed $F(df = 2) = 1.32$, $p = .27$, $\eta^2 = .04$, suggesting that neither condition was experienced as sufficiently stressful to elicit the maternal stress response.

**Figure 1** Header: Cortisol baseline, reactivity, and recovery of infants in the still-face (SF) and still-face with touch (SF+T) conditions. Baseline cortisol was collected upon arrival, reactivity 20 minutes after the SF episode, and recovery 15 minutes after reactivity.

Infants' cortisol levels were individually stable between the second and third assessments, $r = .47$, $p < .001$, indicating that infants whose cortisol reactivity was higher also scored higher at recovery. Mothers' cortisol levels showed medium-level stability across all assessments: between the first and second, $r = .60$, $p < .001$, between the second and third, $r = .42$, $p = .002$, and between the first and third, $r = .50$, $p < .001$. Infant's and mother's baseline cortisol levels were inter-related, $r = .27$, $p = .04$, and infant baseline cortisol correlated with mother cortisol recovery, $r = .36$, $p = .008$, pointing to cross-generation mechanisms in the development of the stress response.

Cardiac vagal tone (Vna)

Descriptive statistics and group differences in infants' and mothers' Vna during the three episodes – play, still-face, and reunion – appear in Table 2.

A repeated measure ANOVA showed that Vna changed across assessments, Sphericity Assumed $F(df = 2) = 3.09$, $p = .05$, $\eta^2 = .11$. The quadratic component was significant, Sphericity Assumed $F(df = 1) = 4.61$, $p = .037$, $\eta^2 = .08$, charting a decrease-increase pattern of cardiac reactivity. As seen (Table 2), no group differences emerged in infants' Vna during free play. In the SF episode, infants in the no-touch condition scored lower than those in the touch condition, indicating a greater vagal suppression in response to the stressful situation. Finally, in the reunion, Vna among infants in the touch condition was similar to the Vna observed during free play, while in the no-touch condition Vna remained the same as during the SF episode (Figure 2). No group differences were found in maternal Vna at any assessment, and a repeated measure ANOVA showed no change in maternal Vna, Sphericity Assumed $F(df = 2) = 1.05$, $p = .21$, $\eta^2 = .03$.

Infants' autonomic reactivity was individually stable across observations. Correlations were: between play and SF, $r = .53$, $p < .001$, between SF and reunion, $r = .45$, $p < .001$, and between play and reunion, $r = .42$,

Table 2 Cardiac vagal tone during the play, still-face, and reunion episodes of the procedure in infants and mothers in the still-face+touch and still-face conditions

	Still-Face+ Touch		Still-Face		<i>F</i>
	Mean	<i>SD</i>	Mean	<i>SD</i>	
<i>Infant</i>					
Play	3.56	.85	3.65	.74	.72
Still-face	3.37	.56	2.74	.68	4.38*
Reunion	3.51	.87	2.83	.75	4.65*
<i>Mother</i>					
Play	5.69	.82	5.48	.85	.78
Still-face	5.63	1.04	5.50	1.19	.15
Reunion	5.51	.76	5.54	.90	.01

* $p < .05$.

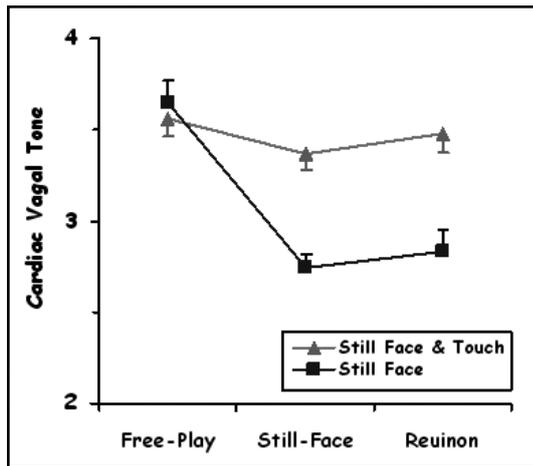


Figure 2 Header vagal tone (*Vna*) during free play, still-face, and reunion of infants in the still-face (*SF*) and still-face with touch (*SF+T*) conditions. Footer: ECG was collected online during the free play, *SF*, and reunion episodes of the paradigm.

$p = .002$. Mothers' *Vna* was highly stable, with correlations between play and *SF*, $r = .77$, $p < .001$, between *SF* and reunion, $r = .86$, $p < .001$, and between play and reunion, $r = .67$, $p < .001$. Infant *Vna* during the *SF* was related to mother *Vna* at reunion, $r = .29$, $p < .05$.

Correlations between *Vna* and cortisol at the three assessments were as follows: T1 (free play and baseline cortisol), $r = .06$, *ns*; T2 (*SF* and cortisol reactivity), $r = .28$, $p < .05$, and T3 (reunion and cortisol recovery), $r = .09$, *ns*. These data suggest that although the baseline functioning of the autonomic and HPA systems is unrelated, the degree of stress reactivity in the two systems is individually stable and infants who experience more stress showed a greater change in both their cortisol and vagal tone. None of the correlations between maternal *Vna* and cortisol were significant.

Infants' behavior during the *SF* differed as a function of maternal touch. Infants in the touch condition fussed and cried significantly less ($M = .30$, $SD = .22$) than infants in the no-touch condition ($M = .45$, $SD = .21$), $F(df = 1, 52) = 4.15$, $p = .04$; gaze aversion was lower in the touch ($M = .31$, $SD = .23$) compared to the no-touch condition ($M = .46$, $SD = .21$), $F(df = 1, 52) = 5.16$, $p = .02$; laughing and cooing were higher in the touch ($M = .07$, $SD = .06$) than in the no-touch condition ($M = .02$, $SD = .03$), $F(df = 1, 52) = 4.96$, $p = .03$. The regulatory behavior of object/body manipulation was significantly higher in the touch ($M = .48$, $SD = .15$) compared to the no-touch condition ($M = .23$, $SD = .24$), $F(df = 1, 52) = 11.01$, $p = .002$; and infants in the no-touch condition kicked significantly more ($M = 0.20$, $SD = .18$) than those in the touch condition ($M = .06$, $SD = .07$), $F(df = 1, 52) = 9.91$, $p = .003$. These data are in line with previous research and demonstrate much weaker behavioral indicators of stress among infants receiving

maternal touch during the still-face paradigm. The findings, therefore, point to consistency between the physiological and behavioral markers of stress.

Touch synchrony and myssynchrony and physiological stress reactivity

Frequencies of touch synchrony during free play were similar in the touch ($M = 29.10$, $SD = 12.33$) and no-touch ($M = 27.37$, $SD = 13.83$) conditions. Similarly, frequencies of myssynchrony were similar in the touch ($M = 9.76$, $SD = 6.60$) and no-touch ($M = 10.98$, $SD = 7.81$) conditions. Touch synchrony was related to lower infant gaze aversion, $r = -.42$, $p < .01$, and myssynchrony to higher gaze aversion, $r = .61$, $p < .001$, pointing to their differential associations with the infant's engagement in the interaction.

Touch synchrony

Frequencies of touch synchrony were related to higher infant *Vna* during free play, $r = .33$, $p = .01$, and marginally related to maternal *Vna* during free play, $r = .26$, $p = .07$. Touch synchrony was unrelated to maternal or infant cortisol.

Touch myssynchrony

Touch myssynchrony, the mother's stimulating and proprioceptive touch while the infant gaze averts, was related to higher maternal cortisol at baseline, $r = .37$, $p < .01$, to cortisol reactivity, $r = .30$, $p < .05$, and marginally related to maternal cortisol at recovery, $r = .24$, $p = .08$. Similarly, correlations were found between tactile myssynchrony and infant cortisol at the reactivity assessment, $r = .27$, $p = .05$. Myssynchrony was also related to lower infant *Vna* during free play, $r = -.28$, $p < .05$.

Discussion

Results of this study demonstrate that maternal touch during moments of simulated maternal deprivation attenuates the human infant's physiological stress response, similar to the effects of touch on young mammals. Two stress-related systems were tested in relation to maternal touch – HPA-axis as indexed by cortisol reactivity and recovery and parasympathetic control as measured by cardiac vagal tone and the vagal brake. Maternal touch reduced the magnitude of the stress response in the two systems, pointing to a multi-dimensional effect of touch and showing its effects on both the immediate response of the autonomic system and the more delayed response of the HPA-axis. Moreover, touch-related components in the mother–infant communication were associated with the functioning of these stress-management systems. Touch

synchrony, the mother's affectionate touch during moments of gaze coordination, correlated with maternal and infant baseline vagal tone, while touch myssynchrony, the provision of strong stimulatory or proprioceptive touch while the infant signals a need for rest, was related to higher maternal cortisol across assessments and to infant cortisol reactivity. These findings support attachment perspectives on the ongoing involvement of the mother's sensitive style in organizing the infant's physiological systems and on the negative consequences of intrusive parenting for the development of physiological and behavioral dysregulation (Carter & Ahnert, 2005). Similar to the long-lasting epigenetic effects of maternal licking-and-grooming on the young mammal's brain structure and function (Champagne, 2008; Meaney, 2001), tactile patterns experienced within the context of early mother-infant interactions possibly carry a long-term impact on the human infant's capacity to manage stress.

The three consecutive measurements of cortisol and vagal tone assessed baseline levels, reactivity to stress, and the system's resilience and recovery from stress. As seen, momentary maternal unavailability, with or without tactile contact, elicited physiological response and both cortisol levels and vagal tone changed in response to the mother's still-face. Yet, touch had two separate effects on the stress response: It decreased the magnitude of the response and it facilitated a quicker recovery to baseline levels. Thus, touch can be said to attenuate the infant's physiological stress reactivity via two types of mechanism – dampening the intensity of the response and increasing the system's resilience following stress, two functions that play a central role in the organism's adaptation to its environment.

Behavioral markers of stress were substantially reduced when maternal still-face was accompanied by maternal touch. Infants in the touch condition exhibited less fussing and crying, gaze aversion, and kicking and more socio-communicative and self-regulatory behaviors. These findings are consistent with previous research (Jean & Stack, 2008; Stack & Muir, 1992) and point to consistency between the physiological and behavioral indicators of stress. When momentary maternal deprivation was upheld by tactile contact, infants spent much of the time (48%) in behaviors that regulate distress through proactive tactics, such as manipulating objects. In contrast, infants in the no-touch condition spent much of their time (45%) in fussing or crying, behaviors that attempt to alleviate distress by arousing the caregiver. During the second 6 months of life, infants' self-regulatory repertoire expands to include more mature and active regulatory behaviors, along the development of grasping, object manipulation, and mobility (Gianino & Tronick, 1986). Perhaps one function of maternal touch during moments of infant distress is the activation of more mature self-regulatory strategies that allow infants to move from the passive forms of regulation typical of the first months of life to

the use of more adaptive, self-organizing modes of regulation.

Another interesting comparison between the behavioral and physiological levels considers the reunion phase of the paradigm. Behavioral studies of the SF show that the reunion episode contains markers of both the SF and free play episodes and suggest that infants are still mildly stressed even after mother resumes communication (Weinberg & Tronick, 1996). Assessment of the HPA-axis functioning, however, showed that when unavailability was not upheld by maternal tactile contact infants were more distressed during reunion than during the SF. It appears that even when young infants can engage in affective communication with the returning unavailable mother, their physiology is still actively responsive to her absence. These findings echo Bowlby's (1969) formulations on attachment, separation, and loss and their bio-behavioral concomitants. The importance of touch during moments of maternal deprivation, therefore, may be in forming a basic relational continuity so that the infant can immediately resume both affective engagement and physiological quiescence. As seen, the absence of touch leaves the infant's distress unregulated, leading to a greater physiological distress rather than reorganization.

Touch synchrony and myssynchrony, important components of the mother-infant communication system, were associated with individual differences in the mother and child's ability to handle stress. Theoretical perspectives on the role of attachment relationships for the infant's bio-behavioral regulation postulate that the mother's ongoing relational style shapes the child's habitual mode of response (Hofer, 1995). Physiological stress-management systems are theorized to be context-dependent and to consolidate during the first postpartum months in relation to specific maternal provisions (Carter & Ahnert, 2005; Meaney, 2001). Consistent with these perspectives, the present findings show that touch synchrony was associated with more optimal baseline functioning of the infant's autonomic system. On the other hand, myssynchrony – the mother's intrusive tactile over-stimulation that overrides the infant signs of diminished engagement – was related to higher maternal cortisol at all assessments, to higher infant cortisol reactivity, and to less optimal infant autonomic response. These findings suggest that tactile over-stimulation impacts both the baseline functioning of the HPA-axis and the magnitude of the stress response. Possibly, the mother's anxious and intrusive style shapes the infant's HPA-axis regulation and autonomic reactivity through complex interactions of genetic, antenatal, and environmental-relational influences. The data showing correlations between the functioning of each system across assessments as well as between maternal and child's cortisol and vagal tone levels lend support to perspectives that highlight the cross-generation transmission of stress regulatory capacities by means of moment-by-moment

interactions within attachment relationships (Feldman, 2007).

The findings have implications for high-risk mother–infant dyads, particularly for the development of touch-related interventions. Several conditions are known to decrease the level of maternal affectionate touch and the degree of touch synchrony during mother–infant interactions, including prematurity (Feldman & Eidelman, 2007), postpartum depression (Feldman & Eidelman, 2003b), infant feeding disorder (Feldman, Keren, Gross-Rozval & Tyano, 2004), multiple births (Feldman & Eidelman, 2004), and transitory brainstem dysfunction (Geva & Feldman, 2008). The present findings, demonstrating links between the provision of touch during moments of stress and the experience of touch synchrony during social interactions with more optimal infant stress regulation, underscore the need to form interventions that enhance the mother's use of affectionate touch and educate mothers as to the central role of touch in alleviating infant distress and promoting positive communication. The finding that the magnitude of the stress responses in the two physiological systems were inter-related and correlated with touch synchrony suggests that increasing the mother's affiliative touch may lead to a multi-dimensional improvement in the infant's physiological reactivity to daily stressors.

Touch – the most fundamental mammalian maternal behavior – has long been considered a critical component in the infant's ultimate capacity to face environmental challenges, regulate stress, and form affiliative bonds. The present study is among the first to include both touch manipulation and micro-analysis of touch synchrony and myssynchrony in a single study and examine their dual effects on hormonal and autonomic stress reactivity. Future research is required to assess the long-term effects of touch on infant physiological resilience and emotional growth, examine the interaction of genetic dispositions and maternal tactile patterns in shaping the stress response, and assess the impact of momentary and stable forms of touch on the human infant's ultimate capacity to manage stress throughout life.

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