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Effects of Human Contact and Vagal Regulation on Pain Reactivity and Visual Attention in Newborns

ABSTRACT: *In two experiments we examined the effects of human contact and vagal regulation on newborns' pain reactivity and visual attention. Baseline cardiac vagal tone was measured during quiet sleep and during the experiment, and vagal withdrawal was indexed as change in vagal tone from baseline to pain (study 1) or attention (study 2). In study 1, 62 healthy newborns were videotaped during a heel-prick procedure and pain reactivity was assessed from micro-level coding of facial expressions, cry behavior, and body movements. Infants were randomly assigned to a contact condition, held by a female assistant, or a no contact condition, on an infant-seat in a similar angle. In study 2, 62 additional healthy newborns, randomly assigned to contact and noncontact conditions, were presented with 2 visual stimuli for a 60 s familiarization period, which were then paired with a novel stimulus. Visual interest, alertness, and novelty preference were coded. Human contact had no effect on the newborns' pain response. Visual attention increased with human contact and newborns in the contact condition looked at the stimuli more frequently, with higher alertness, for longer durations, and had a higher novelty preference. Autonomic reactivity—as indexed by vagal withdrawal-differentiated newborns with intense and mild pain response. Discussion focused on proximity to conspecifics as a contributor to emerging regulatory and adaptive functioning in the human infant. © 2006 Wiley Periodicals, Inc.* Dev Psychobiol 48: 561–573, 2006.

Keywords: *newborns; vagal tone, pain reactivity; visual attention, contact*

INTRODUCTION

Tactile contact is an essential component of mammalian development and the positive effects of early contact on the young animal's stress reactivity, activity level, exploration, and learning have been studied for over five decades (Bernstein, 1951; McClelland, 1956; Meier & Stuart, 1959; Rosen, 1958; Weininger, 1954). Tactile contact in the first postbirth period improves the organization of the biological clock, increases the maturation rate of the autonomic nervous system, and facilitates the regulation of endocrinological and immune functions (Feldman & Eidelman, 2003; Hofer & Shair, 1982; Pauk, Kuhn, Field, & Schanberg, 1986, Soumi, 1995). The positive effects of touch and contact in reducing stress and pain reactivity result not only from active tactile stimulation but also from the mother's global proximity and physical presence (Blass, 1997; Kuhn, Pauk, & Schanberg, 1990; Levine, Stanton, & Gutierrez, 1988). In animal models, effects of contact on stress management have similarly been described for contact by conspecifics, typically an older female (Levine et al., 1988).

Several lines of evidence converge to confirm the beneficial effects of early touch and contact on the human newborn, particularly on the premature infant. Prematurity provides a natural paradigm to assess the effects of maternal deprivation and structured contact in a human model, as premature infants who are cared for in incubators are deprived of full human contact (Feldman, 2004). The most frequently utilized forms of touch

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therapy are massage therapy and skin-to-skin contact and studies of both techniques point to the role of early touch and contact in promoting the infant's attentional capacities and stress regulation. Massage therapy was found to increase the infant's alertness, visual habituation, and orientation to the environment (Field et al., 1986) as well as to improve the organization of sleep and wakefulness in newborns (Scafidi et al., 1990). After receiving tactile stimulation, premature infants show a reduction in cortisol, results which point to the role of contact in regulating stress (Acolet et al., 1993). Long-term effects of massage therapy have also been noted, and premature infants who received tactile interventions showed higher readiness for social interaction at 3 months (Goldstein-Ferber et al., 2005) and more visual novelty preference at 6 months (Rose, 1980). Similarly, full-term neonates who received tactile stimulation showed lower stress responses to inoculation, teeth growth, and constipation (Auckett, 1981; Mclure, 1989) and demonstrated a quicker maturation of the biological clock as observed in melatonin secretion and actigraphy of sleep-wake patterns (Goldstein-Ferber, Laudon, Kuint, Weller, & Zisapel, 2002).

Skin-to-skin contact has similarly been shown to improve stress reactivity and attention in preterm infants. Skin-to-skin contact facilitates the maturation of the vagal tone, improves infants' performance on the habituation and orientation clusters of the Neonatal Behavior Assessment Scale (Brazelton, 1973), and contributes to the organization of sleep-wake patterns (Feldman & Eidelman, 2003). During skin-to-skin contact, newborns cry substantially less than when placed in cots (Michelson, Christensson, Rothganger, & Winberg, 1996), durations of quiet sleep increase (Ludington, 1990), and levels of β-endorphin, cortisol, and cholecystokinin decrease (Mooncey, Giannakoulopoulos, Glover, Acolet, & Modi, 1997; Uvans-Moberg, 1999). Full-term newborns placed in a skin-to-skin position during a heel-prick showed 82% less crying and 65% less facial grimace as compared to infants who were swaddled in the crib during the procedure (Gray, Watt, & Blass, 2000). In addition, skin-to-skin contact was found to have long-term effects on infants' stress reactivity, attention capacities, and learning. Premature infants who received skin-to-skin contact in the neonatal period were better able to regulate negative stimuli at 3 months, displayed higher levels of exploratory behavior at 6 months, and showed more advanced cognitive skills up to 2 years of age (Feldman, 2004; Feldman, Eidelman, Sirota, & Weller, 2002; Feldman, Weller, Sirota, & Eidelman, 2002).

In contrast to research on tactile stimulation, which involves active stroking that impacts on neuro-endocrinological functions (Pauk et al., 1986), and skin-to-skin contact, which regulates infant growth through a complex set of maternal stimuli, (Hofer, 1995), little data are available on the effects of contact by conspecifics on the human newborn. The empirical work of Hofer, spanning over 30 years of systematic research (Hofer, 1973, 1994, 1995; Hofer & Weiner, 1975; Hofer & Shair, 1982), underscores the need to tease apart the separate components of the ''maternal proximity'' constellation and examine its elements in relation to specific physiological systems and emerging skills. As such, addressing the links between specific components of the mother's physical presence and specific capacities of the newborn may further elucidate the mechanisms by which human contact impacts on infant behavior and development.

One mechanism that may account for the role of human contact in reducing stress and increasing visual attention is its buffering effect. According to Gottlieb' (1991) theory on the sequential development of the senses, during the first postbirth period, infants should receive substantially more stimulation to the primary senses–touch and proprioception than to the secondary senses-vision and audition. Moreover, audio and visual stimuli are best presented while infants are being held and human contact can provide a barrier against excessive stimulation. Thus, to further understand the mechanisms by which maternal proximity regulates physiology and behavior in the human newborn, there is a need to tease apart holding by conspecifics from the global complex of maternal proximity and active stroking and examine the differential effects of human contact on the newborn's pain response and visual attention.

Several studies point to the positive effects of human contact on the newborn's pain reactivity and attention. Gormally et al. (2001) compared infants who were held during a heel-prick to those in bassinets and found that the held infants showed less facial grimaces in response to pain. Yet, because there were postural differences between the held infants and those in the cots, it was not possible to determine whether the soothing effect was related to contact or to posture. Korner and Grobstein (1966) tested the effect of holding on visual alertness in crying newborns and found that those who were held to the shoulder stopped crying, opened their eyes, and began scanning their environment. Similarly, Fredrickson and Brown (1975) found that calm newborns in a holding position tended to track a moving object more alertly as compared to newborns not being held.

Stress reactivity and visual attention in newborns are determined not only by external conditions but also by biological dispositions that shape later development. For instance, newborns who reacted intensively to a heel-prick at 2 days also showed higher reactivity to inoculation at 2 months (Woroby & Lewis, 1989) and newborns who cried more to a pacifier withdrawal at 2 days showed more crying during an arm restrained procedure at 5 months (Stifter & Fox, 1990). Similarly, more efficient visual processing in the neonatal period was found to predict higher cognitive skills at 5 months (Sigman, Cohen, & Forsythe, 1981), 5 years (Cohen & Parmelee, 1983), and 8 years (Sigman, Cohen, Beckwith, & Parmelee, 1986), and better functioning on tasks that require attention maintenance and attention shifting at 18 years (Sigman, Cohen, & Beckwith, 1997). These findings point to the long-term associations between stress reactivity and attention skills in the newborn and the child's later regulatory and cognitive capacities.

One indicator of reactivity and visual processing in infants is baseline vagal tone and the vagal tone withdrawal in response to environmental challenges. The vagus is the main nerve of the parasympathetic system, which originates in the brain stem, projects to different organs in the body, and affords a dynamic feedback between brain centers of control and target organs to regulate homeostasis (Porges, 1991). In response to external demands, vagal tone decreases and metabolic output is increased (Porges, Doussard-Roosevelt, & Maiti, 1994). Neonates with higher baseline vagal tone typically show a greater vagal withdrawal in response to challenging event, a pattern considered to index a more optimal functioning of the autonomic nervous system (Porges, 2003), A greater vagal withdrawal, in turn, was found to predict more intense behavioral responses to stress in healthy newborns (Porter, Porges, & Marshall, 1988).

Higher baseline vagal tone has been associated with greater reactivity in early infancy and with more optimal developmental outcomes in the cognitive and social-emotional domains. Infants with higher vagal tone showed a greater behavioral reactivity to the presentation of negative (Huffman et al., 1998) and positive (Fox, 1989) stimuli in the first months of life. Neonatal vagal tone was found to predict better cognitive skills, higher social competence, and less behavior problems across infancy and up to 6 years of age in both full-term and preterm infants (Doussard-Roosevelt, Porges, Scanlon, Alemi, & Scanlon, 1997; Feldman & Eidelman, 2002; Fox & Porges, 1985; Porges, Doussard-Roosevelt, Portales, & Suess P 1994). It is thus of developmental significance to examine correlates of the vagal tone in newborns and to assess whether vagal tone and the vagal withdrawal may moderate the effects of contact on the newborn's pain response and visual attention.

Newborns' baseline vagal tone is related to the intensity of the pain response. Infants with high vagal tone showed greater increase in heart rate in response to a spinal cord puncture (Porter & Porges, 1988), more frequent and intense crying during circumcision (Porter et al., 1988), and higher cortisol increase following a heel-prick (Gunner, Porter, Wolf, Rigatuso, & Larson, 1995). Of interest though, is the fact that although the newborn's facial expressions is the most consistent pain response (Grunau & Craig, 1987; Grunau, Johnston, & Craig, 1990) and the most salient in the communication of pain to the caregiver (Craig, Grunau, & Aquan-Assee, 1988; Hadjistavropoulos, Craig, Grunau, & Johnston, 1994), the relations between vagal tone and newborns' facial expressions in response to pain have not been investigated.

Similarly, with regards to visual attention in newborns, we are aware of no study that examined visual information processing in newborns in relation to vagal tone. In older infants, associations between attention and vagal tone are reported. Six-month-old infants with high vagal tone accumulated 5 s of looking at a stimulus faster, spent less time looking away or with closed eyes during the familiarization period, and showed higher novelty preference than infants with low vagal tone (Linnemeyer & Porges, 1986). Fourteen- and 20-week-old infants with higher vagal tone showed a more efficient processing of visual information (Richards, 1985), and 26-week-old infants with higher baseline vagal were less distracted during the presentation of visual stimuli compared to infants with lower vagal tone (Richards, 1987). Finally, a large vagal withdrawal during a habituation task was found to predict efficient information processing in two and 5-month-old infants (Bornstein & Suess, 2000).

In light of the above, the two studies reported here aimed to examine the effects of human contact and vagal regulation on pain reactivity and visual attention in newborns. Based on research pointing to the positive effects of contact on stress reactivity and attention in animals and on studies demonstrating the role of skin-to-skin contact and massage therapy in the regulation of stress and attention, it was expected that contact would reduce pain reactivity and increase visual information processing in newborns. Specifically, human contact was expected to reduce the pain response to a painful medical procedure, and to increase visual alertness, interest, and learning. To avoid postural difference between groups, infants in the no contact condition were placed on an infant-seat that was tilted to the same angle as the holding position. We expected that vagal regulation would be related to pain reactivity in newborns. In particular, in light of Porges' polyvagal theory (1997, 2003), the withdrawal of the vagal brake was expected to be associated with individual differences in newborns' pain response, above and beyond baseline vagal tone. Thus, we hypothesized that newborns with a greater vagal withdrawal would show a more intense pain response. We also examined the relations between baseline vagal tone and the vagal tone withdrawal with measures of visual attention in newborns. However, because no previous research addressed the links of vagal regulation and visual attention in newborn, these associations were examined as a research question.

METHOD

General Methods

The study included two experiments, assessing the effects of human contact, baseline vagal tone, and vagal tone withdrawal on pain reactivity (experiment 1) and visual attention (experiment 2) in newborns. Both studies took place in a well-baby nursery between 7:30 and 9:00 AM in a separate room near the nursery. The study was approved by the IRB and all participating mothers signed an inform consent.

In each experiment, two 5-min baseline ECG records were taken using a Biolog instrument (model number 3392/6). One record was taken during quiet sleep and the other prior to the experiment, when infants in the experimental group were in the research assistant's arms and infants in the control group were in the bassinet. A third ECG record was taken during the heel-prick in the pain experiment and during the presentation of visual stimuli in the attention experiment. The Biolog is a portable device that is attached by three leads attached to the body and measures the heart rate intervals between two R waves in milliseconds.

Vagal tone, the amplitude of respiratory sinus arrhythmia, was quantified according to the Mxedit system developed by Porges (1985) by a research assistant trained to reliability. After editing to remove artifacts, the Mxedit system converts heart period into time based sampled in 200 ms. intervals, determines the periodicities of heart rate with a 21 point moving polynomial, filters the time-series to extract the heart period within the frequency band of spontaneous breathing of neonates, and calculates the vagal tone index (natural logarithm of variance of the heart period) (Porges, 1985).

STUDY 1: EFFECTS OF HUMAN CONTACT AND VAGAL REGULATION ON NEWBORNS' PAIN REACTIVITY

Participants

Sixty-two healthy newborns participated, 29 males and 33 females. All infants were born in a singleton vaginal birth and received an Apgar score (a measure of the newborn's well being and neurological status), of 7 and above in the 1st and 5th minutes after birth. The newborns' mean age was 51.85 hr ($SD = 7.31$, range = 41–67), mean birth weight was 3350.19 gr. ($SD = 397.87$, range = 2610–4200), and mean gestational age at birth was 39.78 weeks ($SD = 1.14$, range = 37–43). Newborns were randomly assigned to the contact and no-contact groups. Demographic and infant medical information and procedure variables for the two groups are presented in Table 1 and show no differences between groups.

Procedure

Newborns' pain reactivity was measured during a standard heel-prick procedure. The pain stimulus was a

Table 1. Demographic Variables for the Pain and Attention Experiments

	Contact		No contact		Univariate
	M	*SD*	*M*	*SD*	*F*
			Experiment 1: pain response		
Newborn age (hours)	52.27	7.50	51.53	7.41	NS
Birth weight (gr)	3279.00	382.48	3406.36	381.33	NS
Gestational age (weeks)	39.62	1.04	39.90	1.06	NS
Mother age (years)	29.20	4.01	27.30	5.19	NS
Mother education (years)	14.79	2.90	14.46	2.23	NS
Baseline vagal tone	4.40	1.40	3.89	.84	NS
Procedure duration (seconds)	114.70	41.69	118.87	42.73	NS
Number of pricks	1.10	.30	1.03	.18	NS
Number of heal squeezes	15.58	4.06	15.70	4.17	NS
Males/females	14:17		15:16		NS (χ^2)
With/without pain anesthetic during labor	22:8		27:4		NS (χ^2)
			Experiment 2: Visual attention		
Newborn age (hours)	54.28	9.51	52.96	7.42	NS
Birth weight (gr)	3417.25	319.72	3320.82	434.67	NS
Gestational age (weeks)	39.60	1.06	39.58	1.15	NS
Mother age (years)	28.92	6.15	28.13	5.78	NS
Mother education (years)	15.17	1.65	14.31	1.62	NS
Baseline vagal tone	4.62	1.20	4.54	1.16	NS
Males/females	14:17		19:12		NS (χ^2)
With/without pain anesthetic	16:15		21:10		NS (χ^2)

routine heel-prick conducted for the PKU, a routine metabolic screening test of all newborns. The newborns' heel was pricked by a Tenderfoot lancet (I.T.C). Mean duration of the procedure was 114.80 s ($SD = 42.07$ s, range = 43.2–231.7), the mean number of pricks was 1.06 ($SD = .24$, range = 1–2), and the mean number of heel squeezes was 15.46 ($SD = 4.10$, range = 4–24). The same nurse applied the heel-prick to all newborns.

Following 5 min of ECG baseline recording during quiet sleep, infants were moved to an infant-seat (control group) or to the research assistant's arms (experimental group). Both the research assistant and the infant were dressed during the experiment and no skin-to-skin contact was involved. Infants were held by a female research assistant with the infant's head in the crook of the left arm so that the left leg was available for the heel-prick sampling. The infant chair was tilted in a 60-degree angle and the infant sat in the same angle as in the experimental condition. Infants' ECG was recorded for a second baseline prior to the prick for approximately 5 min and for a third time during the heel-prick procedure. Newborns were videotaped during the heel-prick for later coding.

Coding

The newborns' behavioral responses were coded on a computerized system (The Observer, Noldus Co.) while the tape was running in slow motion. Pain reactivity was coded as follows: Facial activity was coded according to the Neonatal Facial Coding System (NFCS; Grunau & Craig, 1987), which has been validated (Craig, Hadjistavropoulos, Grunau, & Whitfield, 1994) against Ekman's Facial Action Coding System (Ekman & Frisen, 1978). The following codes are included in the NFCS: brow bulge, eye squeeze, naso-labial furrow, open lips, stretch mouth (vertical), stretch mouth (horizontal), lip purse, taut tongue, and chin quiver (For a detailed description of each facial feature see Grunau & Craig, 1987). In addition, cry and body movements were coded. Cry was defined as an audible negative vocalization associated with a facial grimace following Blass, Fillion, Rochat, Hoffmeyer, and Metzher (1989). Movement was coded when there was a movement of one of the infant's limbs, head, or torso. Proportions (%) of the different pain responses out of the entire pain episode and latencies in seconds to the expression of each response were later calculated from the computerized coded data.

Coding was conducted by two coders who were blind to the study's hypotheses. Inter-rater reliability was examined on 15 cases and were as follows: movements, 87%; cry, 91%; brow bulge, 95%; eye squeeze, 96%; nasolabial furrow, 91%; open lips, 99%; stretch mouth (vertical), 98%; stretch mouth (horizontal), 94%; lip purse, 100%; taut tongue, 95% and chin quiver, 100%. *Kappas* for inter-rater reliability averaged .90 (range = .88–.93).

Statistical Analysis

Factor analysis was conducted on the behavioral variables coded from the videotapes of the infants' response to the heel-prick procedure to create a pain response composite. ANOVA with repeated measures was used to address changes in vagal tone and heart period in response to pain. Infants were divided into high- and low-reactivity groups according to baseline vagal tone and vagal tone withdrawal using the median split, as is customary in developmental research. A MANOVA was used to address the effects of human contact, baseline vagal tone, and their interaction on cardiac and pain measures. A MANCOVA was used to assess human contact, vagal tone withdrawal group, and their interaction on pain measures while controlling for baseline vagal tone. This analytic strategy was used to examine the effects of human contact, cardiac measures, and their interaction on the pain reactivity and visual attention (in experiment 2) measures.

RESULTS

Change in Heart Period and Vagal Tone in Response to the Heel-Prick

An ANOVA with repeated measures applied to the newborns' heart period and vagal tone during undisturbed sleep, preprocedure, and heel-prick showed a significant main effect for heart period, *Wilks' F*(d*f* = 2, 55) = 56.37, $p < .001$, and for vagal tone, *Wilks' F*(d*f* = 2, 55) = 26.99, $p < .001$. Means for infant vagal tone during undisturbed sleep, preprocedure, and the pain procedure are presented in Figure 1.

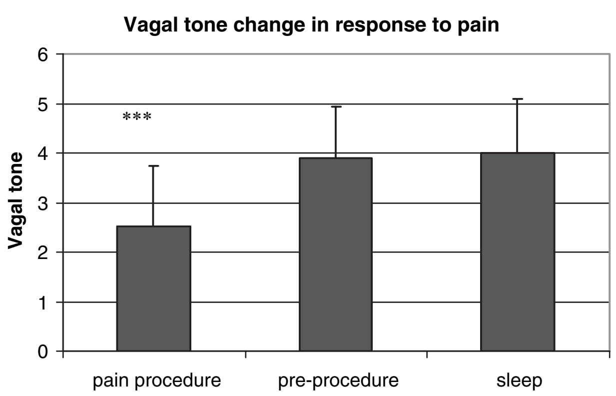

FIGURE 1 Mean vagal tone during sleep, pre-procedure and pain procedure. ***$p < .001$.

Results of the ANOVA showed no differences between heart-period and vagal tone during undisturbed sleep and between the preprocedure measurement. Differences were found between heart period and vagal tone during the heel-prick and between those measures during undisturbed sleep: heart period $F(df = 1,120) = 107.64$, $p < .001$; vagal tone $F(df = 1,120) = 55.37$, $p < .001$. Similarly, differences were found between heart period and vagal tone during the heel-prick and between those measures before the procedure; heart period $F(df = 1,115) = 87.01$, $p < .001$; vagal tone $F(df = 1,115) = 44.42$, $p < .001$. Mean baseline vagal tone during quiet sleep was 3.99 ($SD = 1.10$) and mean heart period was 520.59 ms ($SD = 56.42$). Mean vagal tone prior to the heel-prick was 3.89 ($SD = 1.04$), and heart period was 512.98 ms ($SD = 55.30$). Mean vagal tone during the heel-prick was 2.51 ($SD = 1.22$) and mean heart period was 415.75 ms ($SD = 59.33$). Vagal tone and heart-period during quiet sleep and before the heel-prick were correlated, $r = .66$, $p < .001$, $r = .72$, $p < .001$ respectively.

Due to the fact that the two measures of baseline were highly correlated and not significantly different from each other, but both showed significantly differences from the procedure, we averaged the vagal tone and heart period data from the quiet sleep and the preprocedure into a single ''baseline'' measure. The reason for conducting baseline assessment during both quiet sleep and pre-procedure is related to the fact that numerous studies assessing longitudinal correlation from neonatal vagal tone to developmental outcomes used vagal tone during quiet sleep (e.g., Doussard-Roosevelt et al., 1997; Huffman et al., 1998). The averaged baseline measure showed a mean vagal tone of 3.94 ($SD = .98$, range $= 2.25–7.03$) and a mean heart period of 516.79 ($SD = 52.03$, range $= 399.08–735.38$). Vagal tone withdrawal and heart period decrease in response to the heel-prick were calculated as the difference between the baseline vagal tone and heart period composites and the vagal tone and heart period measured during the heel-prick. Mean vagal tone withdrawal was 1.43 ($SD = 1.46$, range $= -1.82–+5.19$). Mean heart period decrease was 101.03 ms ($SD = 71.49$, range $= -31.00–+329.68$). Most infants showed a vagal tone decrease in response to the heel-prick, and only 10 infants showed a vagal tone increase; χ^2 ($1, N = 62 = 5.05, p < .05$).

Pain Response, Autonomic Reactivity, and Human Contact

Proportions and latencies for the separate behavioral pain responses during the heel-prick are summarized in Table 2.

Table 2. Proportions and Latencies for Behavioral Pain Responses During the Heel-Prick

Behavioral pain response	Proportion (%)		Latency (seconds)	
	M	*SD*	*M*	*SD*
Naso-labial furrow	42.28	34.03	12.89	17.60
Body movement	41.80	30.64	14.50	13.76
Eye squeeze	41.40	33.78	13.45	19.13
Brow bulge	41.21	31.78	11.68	16.34
Open lips	40.72	37.84	15.69	17.30
Cry	32.68	34.17	24.34	25.61
Strech mouth vertical	25.63	31.15	31.75	30.21
Taut tongue	18.74	26.87	36.43	31.08
Stretch mouth horizontal	6.74	10.23	20.55	23.84
Chin quiver	4.81	14.31	73.93	58.33
Lip purse	.20	.92	77.42	36.77

A factor analysis conducted for the facial expression and cry behaviors revealed that the majority of these codes loaded on a single factor, which had an Eigenvalue of 6.40 and explained 64.06% of the variance. Variables with loading of .80 and above on this factor were averaged into the Pain Response composite. These included eye squeeze, naso-labial furrow, open lips, cry, stretch mouth vertical, brow bulge, and taut tongue. The latency to the pain response composite component that appeared first in each subject was regarded as the latency to the pain response.

Correlations were found between baseline vagal tone and vagal tone withdrawal, $r = .55$, $p < .001$, and baseline vagal tone and heart period decrease $r = .55$, $p < .001$. No correlations were found between baseline vagal tone and the pain response composite, $r = .16$, NS, the latency to the pain response, $r = -.06$, NS, and to body movement duration, $r = .13$, NS, and body movement latency $r = -.08$, NS.

Correlations were found between vagal tone withdrawal and heart period decrease $r = .86$, $p < .001$, the duration of the pain response composite, $r = .71$, $p < .001$, the latency to the pain response, $r = -.34$, $p < .01$ and to body movement duration, $r = .60$, $p < .001$. No correlation was found between vagal tone withdrawal and body movement latency $r = .12$, NS.

Newborns were divided into a high and low vagal tone groups according to their baseline vagal tone using the median split (median $= 3.93$). A MANOVA with contact condition and vagal tone group as the between-subject factors was conducted assessing differences in vagal tone withdrawal, heart period reduction, the pain response, the latency to the pain response, body movements, and the latency to body movements. No main effects were found for contact. On the other hand, an overall main effect was found for high/low baseline vagal tone, *Wilk's* $F(df = 6, 48) = 2.99$, $p < .05$. Univariate analysis indicated that infants in the high vagal tone group showed a larger vagal tone withdrawal $F(df = 1, 53) = 7.67$, $p < .01$, and a greater heart period reduction $F(df = 1, 53) = 5.78$, $p < .05$. Newborns with high baseline vagal tone showed a mean vagal tone reduction of 1.94 ($SD = 1.63$), and a mean heart period reduction of 122.9 ms ($SD = 74.67$), while newborns with low baseline vagal tone showed a mean vagal reduction of .90 ($SD = 1.03$), and a mean heart period reduction of 78.37 ms ($SD = 61.41$). No effects were found for baseline vagal tone on the pain response composite, the latency to the pain response, body movement durations, or the latency to body movements.

Next, we further divided the newborns according to the vagal tone withdrawal using the median split (median Vna = 1.59) into a high- and low- vagal withdrawal groups. A MANCOVA assessing differences in the pain response, the latency to the pain response, body movements, and the latency to body movements with contact and vagal tone withdrawal groups as the between subject factors, and baseline vagal tone as a covariate, was conducted. An overall main effect for high/low vagal withdrawal groups was found, *Wilk's* $F(df = 4, 42) = 10.16$, $p < .001$, while controlling for baseline vagal tone. Univariate analysis, presented in Table 3, indicated that newborns with a greater vagal tone withdrawal exhibited longer durations of the pain response composite, shorter latencies to the pain response, and longer durations of body movements during the heel-prick.

Summary. Contrary to our hypothesis, human contact did not reduce the pain response in neonates. On the other hand, the intensity of the pain response was associated with vagal tone indices. Infants with higher baseline vagal tone showed more intensive cardiac response to the heel-prick, as expressed in more vagal tone withdrawal and heart rate increase. Infants with a greater vagal withdrawal showed more intense pain reactivity, as expressed in longer durations of the pain response, shorter latencies to the pain response, and more body movements during the procedure.

STUDY 2: EFFECTS OF HUMAN CONTACT AND VAGAL REGULATION ON NEWBORNS' VISUAL ATTENTION

Participants

Sixty-two additional newborns (who did not participate in Study 1) participated in this study (33 males and 29 females). All infants were born in a vaginal delivery with an Apgar score of 7 and above in the 1st and 5th moments. Newborns' mean birth weight was 3359.37 gr. ($SD = 372.95$, range = 2340–4260), mean gestational age at birth was 39.66 weeks ($SD = 1.11$, range = 37–42), and mean age at testing was 53.50 hr ($SD = 8.29$, range = 40–76). Demographic variables in the two groups are presented in Table 1.

Procedure

Infants who were in a calm wakefulness state after their morning bath were moved in the bassinet to a separate room near the nursery. In the control group the infant was seated in an infant-seat tilted to a 60-degree angle. In the experimental group, the infant was placed in the arms of a research assistant, who held the infant facing forward and supported him/her under the arms with her hands. Both the research assistant and the infant were dressed during the experiment and no skin-to-skin contact was involved. The visual stimuli were presented for a total of a minute and a half and the infant's response was recorded by a video camera. ECG was recorded during undisturbed sleep in the bassinet, during stimuli presentation, and during a time with no visual stimuli presentation while the

Table 3. Pain Responses in High and Low Vagal Withdrawal Groups

	Low vagal withdrawal ($n = 28$)		High vagal withdrawal ($n = 29$)		
	M	*SD*	*M*	*SD*	
Pain response duration (%)	13.95	5.80	59.97	5.50	29.47***
Pain response latency (seconds)	18.06	3.54	4.94	3.36	6.40*
Body movements duration (%)	24.20	6.15	61.02	5.84	16.77***
Body movements latency (seconds)	16.77	2.91	9.84	3.06	NS

*$p < .05$, ***$p < .001$

infant was still awake in the infant chair or in the research assistant arms.

Visual Stimuli and Apparatus

The visual stimuli were three black-and-white checkerboards measuring 15 × 15 cm, as described in Friedman (1972). One board was divided into 9 equal squares, a second board was divided to 25 equal squares, and a third board was divided into 64 equal squares. The stimuli were presented in two square windows sized 15 × 15 cm that were opened in a black board, with a 5-cm distance between the windows. A round opening hole on top enabled the recording of the infant responses with a video camera. Two additional boards were connected to the main board to form a cell that blocked the infant's visual field. The visual stimuli were held in two pockets behind the board's windows and were covered by two black covers. When the experiment began the covers were removed and exposed the first pair of stimuli. After 30 s, the first pair of stimuli was removed and the second pair was exposed, which included the same stimuli as in the first pair switched for positions. After additional 30 s of familiarization the second pair was removed and exposed the third pair that included one of the previously presented stimuli switched for position and a new stimulus. This pair was presented for a test period of 30 s. The stimuli were presented at a distance of approximately 50 cm from the infant's eyes.

Coding

Coding was conducted using the same computerized system as that of the pain response while the tape was running in slow motion. Two channels of looking behavior were coded:

1. Looking duration and direction—whether the infant gazed at the right stimulus, left stimulus, or elsewhere.
2. Visual Alertness—in line with Sigman, Kopp, Parmelee, and Jeffrey (1973) this code addresses the infants' mode of looking at the stimuli and includes the following codes: looking with wide eyes and eye movements; narrow eyes with eye movements; wide eyes without eye movements; narrow eyes without eye movements; and closed eyes.

Two coders, unfamiliar with the study's hypotheses, coded the infant's gaze behavior. Inter-rater reliability, computed for 14 infants, was as follows; looking at the right stimulus, 92%; looking at the left stimulus, 91%; looking to another place, 86%. Wide eyes with eye movements, 87%; wide eyes without eye movement, 89% narrow eyes with movement, 84%; narrow eyes without movement, 80%; closed eyes, 97%. *Kappas* for inter-rater reliability averaged .86 (range = .79–.91).

Statistical Analysis

ANOVA with repeated measures was used to address changes in vagal tone and heart period in response to the visual stimuli presentation. Infants were divided into high- and low-reactivity groups according to baseline vagal tone and vagal tone withdrawal using the median split. A MANOVA was used to address the effects of human contact, baseline vagal tone, and their interaction on infants' visual attention and novelty preference. A MANCOVA was used to assess human contact, vagal tone withdrawal group, and their interaction on attention measures while controlling for baseline vagal tone.

RESULTS

Change in Newborns' Heart Period and Vagal Tone in Response to Visual Stimuli

ANOVA with repeated measures applied to the newborns' heart period and vagal tone during sleep, wakefulness, and visual stimuli presentation showed a significant main effect for heart period,' *Wilks'* $F(\mathrm{d}f = 2,\ 57) = 19.84$, $p < .001$, and for vagal tone, *Wilks*' $F(\mathrm{d}f = 2, 56) = 14.92$, $p < .001$. Repeated measures of vagal tone during undisturbed sleep, wakefulness, and picture presentation are presented in Figure 2.

Results showed no differences in heart-period and vagal tone between wakefulness and the visual stimuli presentation. Differences were found between heart period and vagal tone during sleep and wakefulness as follows; heart period, $F(\mathrm{d}f = 1,\ 119) = 28.89$, $p < .001$,

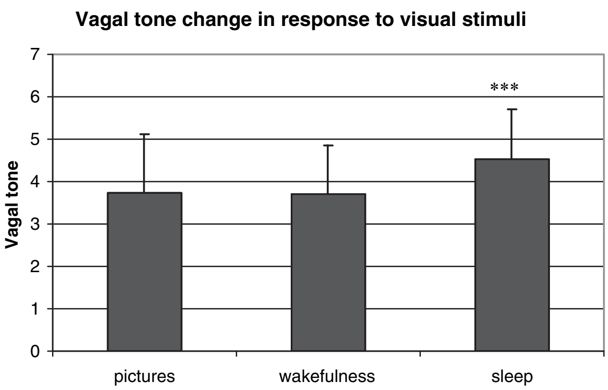

FIGURE 2 Mean vagal tone during sleep, wakefulness and picture presentation. ***$p < .001$.

and vagal tone, $F(df = 1, 119) = 15.77$, $p < .001$ and between sleep and visual presentation as follows; heart period, $F(df = 1, 120) = 20.84$, $p < .001$, and vagal tone, $F(df = 1,1\ 19) = 10.19$, $p < .01$. Infants' mean baseline vagal tone during quiet sleep was 4.52 ($SD = 1.20$) and mean heart period was 531.86 ms ($SD = 55.06$). Mean vagal tone during wakefulness was 3.70 ($SD = 1.14$), and heart period was 484.24 ms ($SD = 45.16$). Mean vagal tone during visual stimuli presentation was 3.75 ($SD = 1.36$) and mean heart period was 487.14 ms ($SD = 55.86$). Mean vagal tone withdrawal from sleep to picture presentation was .75 ($SD = 1.23$, range $= -1.39$–$+3.27$). Twenty-one infants showed a vagal tone increase from sleep to picture presentation, whereas 38 showed a vagal tone decrease.

Vagal tone was individually stable across the three observations. Correlations between wakefulness and visual presentation were, $r = .79$, $p < .001$, between sleep and wakefulness were, $r = .53$, $p < .001$, and between sleep and visual stimuli presentation were, $r = .54$, $p < .001$.

Visual Attention, Human Contact, and Cardiac Reactivity

Baseline vagal tone was related to vagal tone withdrawal $r = .36$, $p < .01$ and to heart period decrease $r = .26$, $p < .05$ from sleep to picture presentation. No correlations were found between baseline vagal tone and looking frequency $r = .03$, NS, looking duration $r = .01$, NS, looking with wide eyes $r = .06$, NS, looking with eye movements $r = -.04$, NS, closed eyes $r = -.05$, NS, and novelty preference $r = .02$, NS.

Vagal tone withdrawal was related to heart period decrease from sleep to picture presentation $r = .73$, $p < .001$. No correlations were found between vagal tone withdrawal and looking frequency $r = .18$, NS, looking duration $r = .06$, NS, looking with wide eyes $r = .12$, NS, looking with eye movements $r = .19$, NS, closed eyes $r = .09$, NS, and novelty preference $r = .22$, NS.

Infants were divided into two groups based on the median split of baseline vagal tone (median = 4.57). Vagal withdrawal was calculated as the difference between vagal tone during sleep and during stimuli presentations and two groups were formed based on the median split in vagal withdrawal (median = .85).

A MANOVA assessing the effects of human contact and high/low baseline vagal tone groups on looking frequency, looking duration, looking with wide eyes, looking with eye movements, closed eyes, and novelty preference was conducted. A significant overall main effect was found for human contact, Wilks' $F(df = 6, 48) = 3.43$, $p < .01$. Univariate analysis, shown on Table 4, indicated that the differences between the contact and no contact conditions were related to the looking frequency, looking time duration, looking with wide eyes, looking with eye movement and novelty preference. Infants in the contact condition looked at the stimulus more frequently, for longer periods, with wider eyes, and with more eye movement, indicating better attentional processes. These infants also preferred the novel stimulus, indicating more efficient learning and memory processes. No effects for vagal tone groups were found.

A MANCOVA was conducted for the same attention measures with contact and vagal withdrawal groups as the between subject factors and baseline vagal tone as a covariate. The same overall main effect was found for human contact. No effects for vagal withdrawal groups emerged and no interaction between vagal tone and contact or between vagal withdrawal and contact was found for any of the visual attention variables.

Summary. In line with our hypothesis, human contact enhanced visual attention in neonates. Infants in the contact condition looked at the stimuli more frequently, for longer duration, looked more alertly, and showed higher novelty preference as compared to infants in the no

Table 4. Visual Attention in Contact and no Contact Groups

	Contact		No contact		Univariate
	M	*SD*	*M*	*SD*	*F*
Looks frequency (number)	9.20	3.80	6.81	3.03	6.53*
Looking duration (seconds)	68.22	17.33	54.35	24.01	6.35*
Looking with wide eyes (seconds)	44.93	28.58	18.22	24.02	13.88***
Looking with eye movement (seconds)	40.71	20.65	21.79	22.66	10.81**
Novelty preference (%)	57.66	38.59	33.44	41.45	5.23*
Eyes closed (seconds)	6.45	6.9	5.09	11.10	NS

*$p < .05$.
**$p < .01$.
***$p < .001$.

contact condition. No effects for vagal tone were found for newborns' visual attention.

DISCUSSION

Results of this study—the first to examine pain responsivity and visual attention in term neonates in relation to both human contact and cardiac vagal tone—demonstrate that while human contact had no effect on the pain response, contact improved visual attention and information processing in newborns. Vagal tone indices were related to the newborn's pain reactivity and neonates with higher baseline vagal tone and a greater vagal withdrawal displayed a more intense pain response. On the other hand, the visual attention system, which is not yet fully developed at birth, was not related to measures of neonatal vagal tone.

Human contact had a positive effect on several dimensions of visual information processing in newborns. As noted, contact increased visual alertness, as measured by the proportion of time infants looked at the stimuli with wide and open eyes accompanied by eye movements. These findings are consistent with those of Korner and Grobstein' (1966), who showed that placing infants on the shoulder reduced crying and increased visual alertness. It thus appears that the effect of human contact on visual alertness is independent of the newborn's initial arousal state. In addition to visual alertness, contact also increased the number of times the infant gazed at the stimulus and, consequently, increased cumulative looking time. These findings are consistent with those of Fredrickson and Brown (1975), who showed that contact enhanced newborns' ability to track a moving object. The present data indicate that human contact is efficient not only in enhancing newborns' visual tracking, but also in increasing their ability to direct gaze and investigate a static visual stimulus.

In addition to enhancing visual alertness, interest, and total gaze duration, contact also increased the newborn's preference for novel stimuli over familiar ones. Studies in animal models demonstrate that visual stimulation in the neonatal period has a long-term impact on later development. Rat pups exposed to visual stimuli in early life showed a better performance on an open field test, in a maze test, in a visual discrimination and generalization test, and in a spatial problem test. These pups also demonstrated more exploratory behavior in a new environment (Forgus, 1954; Hymovitch, 1952). Similarly, human infants who were visually stimulated by their parents at 9 months showed better visual habituation at 12 months (Riksen-Walraven, 1978). Increasing visual alertness and information processing by means of human contact may therefore be one pathway by which tactile stimulation and skin-to-skin contact improve the infant's cognitive skills, habituation performance, and exploratory behavior in later infancy (Feldman, Weller et al., 2002; Field et al., 1986; Rose, 1980). Because indices of visual information processing in infancy are among the strongest predictors of cognitive development in later childhood and adolescence (Rose & Wallace, 1985, McCall & Carriger, 1993; Rose & Feldman, 1995), it is important to detect mechanisms that may enhance visual processing and novelty preference already at the newborn stage.

Contrary to our expectation, human contact did not decrease the newborns' pain response. Our results differ from those of Gormally et al. (2001), who showed that contact and sucrose water reduced facial grimace in response to a heel-prick in newborns. One possible explanation may relate to the fact that in the Gormally et al.'s study the experiment and control groups differed in their postural position and this may have allowed for a freer blood flow to the heel, less heel squeezes, and less pain. Much further research is required to elucidate the specific effects of contact on components of the stress response in the human newborns and the mechanism by which the pain response may be modified. Our findings also differ from those of Gray et al. (2000), who demonstrated that skin-to-skin contact reduced crying and facial grimace in response to a heel-prick. However, the skin-to-skin experience incorporates more elements of the "maternal proximity" constellation than human contact. It involves the mother rather than a female conspecific and the skin-to-skin mode is more conducive for thermoregulation, synchrony of body rhythms, infant exposure to familiar (and potentially soothing) maternal body odors, and the experience of specific maternal stimuli. Newborns can distinguish specific maternal stimuli, such as face, voice, and smell, and show clear preference to mother-related stimuli already in the first days after birth (Bushnell, Sai, & Mullin, 1989; DeCasper & Fifer, 1980; Macfarlane, 1975). Possibly, maternal holding rather than holding by a female adult would have been more efficient in reducing the newborns' pain responses as compared to the nonspecific human contact examined here. It is also possible that for a highly aversive stimulus, such as the heel-prick, only the full skin-to-skin experience, which is similar to the maternal proximity constellation in other mammals, may be effective in reducing stress and pain reactivity.

Infants' baseline vagal tone and the vagal withdrawal were related to different components of the pain response. Newborns with higher baseline vagal tone showed a greater change in vagal tone and in heart period in response to pain as compared to newborns with low baseline vagal tone. These findings are consistent with previous research, who showed that newborns with higher baseline vagal tone also showed a greater decrease in both vagal tone and heart period in response to painful medical procedures, such as spinal cord puncture (Porter & Porges, 1988) and circumcision (Porter et al., 1988). Newborns' cry and facial expression response duration and latency were not associated with baseline vagal tone, but with the vagal withdrawal in response to the painful procedure. According to Porges' (1997) model of the ''vagal brake,'' it is the removal of the vagal tone that allows for energy mobilization, intensive action of the muscles, and the execution of the ''fight or flight'' response and the present findings are consistent with the theoretical model.

The association of pain, but not attention with the cardiac measures may be related to the different developmental course of the two systems. The pain perception system develops much earlier than the visual attention regulation system. As early as the 7th week of gestation, sensory receptors begin to develop, spread to all sensory surfaces by the 20th week (Humphrey, 1964), and by the 24th week thalamocortical synapses between incoming sensory fibers and the cortex are established (Kostovic & Goldman-Rakic, 1983). The maturity of the pain perception system at birth enables the newborn to mobilize energy in response to pain. On the other hand, the visual attention regulation system is immature at birth. The saccadic eye movements system is still reflexive and control of the posterior attention system and the frontal eye field on saccadic eye movements emerge only during the first months of life (Richards & Casey, 1992). This immaturity may account for the disassociation between visual attention and vagal tone indices in the newborn. When sustained attention is developed later in infancy, visual attention measures become associated with heart period and vagal tone (Bornstein & Suess, 2000; Linnemeyer & Porges, 1986, Richards, 1985, 1987). Important to note, however, that the openness of the visual system to further maturation allows for a greater environmental impact on the functioning of this system, as seen by the finding that human contact enhanced the infant's immature visual attention functioning, but not the more mature system controlling the pain response.

Future research may further delineate the specific stimuli involved in human contact that are necessary and sufficient to reduce the pain response and increase visual attention in newborns. Assessing the effects of contact on newborns' attention in different postural positions, such as the breastfeeding position, may afford a broader view on the effects of human contact on processes of learning and exploration. As to the pain response, it appears that human contact by a conspecific is not sufficient to reduce pain, and future research should address the effects of maternal holding and skin-to-skin contact by a conspecific on the newborn's stress response. Research on the effects of contact on stress reactivity and attention regulation in young infants is essential in order to utilize contact—a natural and common resource in the infant's caregiving environment—in the service of the child's well-being and development.

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