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Touch for socioemotional and physical well-being: A review

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ABSTRACT

This review briefly summarizes recent empirical research on touch. The research includes the role of touch in early development, touch deprivation, touch aversion, emotions that can be conveyed by touch, the importance of touch for interpersonal relationships and how friendly touch affects compliance in different situations. MRI data are reviewed showing activation of the orbitofrontal cortex and the caudate cortex during affective touch. Physiological and biochemical effects of touch are also reviewed including decreased heart rate, blood pressure and cortisol and increased oxytocin. Similar changes noted following moderate pressure massage appear to be mediated by the stimulation of pressure receptors and increased vagal activity. Increased serotonin and decreased substance P may explain its pain-alleviating effects. Positive shifts in frontal EEG also accompany moderate pressure massage along with increased attentiveness, decreased depression and enhanced immune function including increased natural killer cells, making massage therapy one of the most effective forms of touch.

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Introduction

Touch has been referred to as the fifth sense and the least researched of the senses (Montagu, 1971). In his seminal book called *Touching*, Montagu raised many questions about the role of touch, mostly in communication and across cultures. In a more recent book called *Touch* an attempt was made to address some of these questions raised by Montagu (Field, 2001). The current review primarily summarizes research published between 2001 and the date of this publication. Brief summaries are provided on studies on the role of touch in early development including touch deprivation and touch

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aversion, on touch in communication including emotions and personal relationships, on physiological and biochemical effects of touch, on massage therapy effects on various conditions including prematurity, pain, attentiveness, depression and immune function and on virtual reality touch.

Touch in early development

The skin is the oldest and the largest of our sense organs, and the first to develop (Field, 2001; Montagu, 1971). The fetus experiences touch by being suspended in amniotic fluid and receiving tactile stimulation through the mother's abdominal wall, typically showing this by increased activity (Dieter, Field, Hernandez-Reif, Emory, & Redzepi, 2003; Lagercrantz & Changeux, 2009). The newborn continues to receive significant stimulation through being cuddled and breastfed. This caregiving touch is not only essential for growth and development but has also been actively used to calm infants in pain and discomfort (Bellieni et al., 2007), most especially the parent holding the infant skin-to-skin, as in "kangaroo care" (Ferber, Feldman, & Makhoul, 2008).

The infant, in turn, discovers most of its world in the early months by touching. The use of touch begins prenatally as in the fetus thumb-sucking and grabbing the umbilical cord. Grasping then allows newborns to perceive the texture of objects as well as their weight and temperature (see Field, Hernandez-Reif, & Diego, 2010 for a review; Sann & Streri, 2008). These skills have been demonstrated by newborns differentially sucking on a nubby versus a smooth nipple (Hernandez-Reif, Field, & Diego, 2004), by their differential grasping of warm versus cold temperature tubes (Hernandez-Reif, Field, Diego, & Largie, 2003) and by their holding a heavier tube of many pellets differently than holding a lighter tube of fewer pellets (Hernandez-Reif, Field, Diego, & Largie, 2002). Some infants show more limited performance on these tasks, for example, infants of depressed mothers (Field, Diego, Hernandez-Reif, Deeds, & Figueiredo, 2010). However, it is unclear from these studies whether these high-risk infants have limited perceptual abilities or limited performance due to inattentiveness and/or less exploratory behavior. Further research is needed to explore these variables as well as other potential underlying mechanisms such as different arousal levels.

As infants move into the second 6 months of life, they show refined object-oriented motor responses in manipulating objects (Corbetta & Snapp-Childs, 2009). By that time, infants have had repeated experiences with seeing, reaching, touching, grasping and manipulating objects varying in size and texture. But they also develop locomotion skills which would allow greater access to objects (as in the need for "baby-proofing" living spaces) but might also compete for the infants' attention.

The types of caregiving touch infants receive across the first year of life may also have differential effects. Caregiving touch has been studied in both the home (Ferber et al., 2008) and in infant daycare (Field et al., 1994). During natural caregiving and mother-child play sessions in the home, affectionate, stimulating and instrumental types of touch have been studied (Ferber et al., 2008). Maternal affection and stimulating touch decreased significantly during the second 6 months of life. This may relate to the infants' accelerated gross motor development at this time, namely crawling and walking, that would naturally move infants away from close physical contact with their mothers. Similarly, in infant daycare, affectionate forms of touch such as hugging, kissing and stroking decreased in later infancy and the toddler years (Field et al., 1994). However, reciprocal communication increased in the second half-year of life and was predicted by the frequency of affectionate touch that occurred in the first half-year of life.

Touch deprivation

Infants and children in institutional care typically receive minimal touching from caregivers which is related to their later cognitive (MacLean, 2003), and neurodevelopmental delays (Chugani et al., 2001; MacLean, 2003; Nelson, 2007). The cognitive skills of these deprived children are often below average when compared to same-age children who are raised in families. Unfortunately, this deprivation and the associated developmental delays appear to persist for many years after adoption (Beckett et al., 2006).

Touch deprivation also occurs for infants of depressed mothers (Field, 2001). For example, in one study, infants of depressed mothers, in contrast to those of non-depressed mothers, spent greater periods of time touching themselves, appearing to compensate for the less frequent positive touch

from their mothers (Herrera, Reissland, & Shepherd, 2004). They also used more active types of touching (i.e. grabbing, patting and pulling) than infants of non-depressed mothers during stressful situations, as if calming themselves (Moszkowski et al., 2009).

Mothers of high-risk infants, for example low birthweight infants, have been noted to help reduce their infants' developmental delays by massaging them (Weiss, Wilson, & Morrison, 2004). In another study, depressed mothers who massaged their infants showed more affectionate touch, and their infants were more responsive (Field et al., 1996). The mothers also benefited from providing additional touch. Depression has decreased in depressed mothers, and their infants' growth and development have improved following a period of the mothers giving them massages (Goldstein-Ferber, 2004; O'Higgins, St James Roberts, & Glover, 2008). The sensitivity and responsivity of mothers during interactions with their infants and the responses of the infants have also been significantly improved both in non-depressed and depressed mothers and their infants (Field et al., 1996; Lee, 2006). These studies highlight the fact that the massager also benefits simply from giving the massages. This would not be surprising given that pressure receptors are also stimulated in the hands of the person providing the massage, and it is the stimulation of pressure receptors that mediates the positive effects of massage (Field et al., 2010). Short-term stress levels have also been positively affected by compensatory stimulation. For example, premature infants had lower cortisol levels after being held by their mothers (Neu, Laudenslager, & Robinson, 2009). During the holding period, the mothers cortisol levels also decreased (Neu et al., 2009). Demonstrating the mutual or reciprocal effects of touch is a complex measurement problem, but this co-regulation of cortisol paradigm is a good model for further research. Touch behaviors that would lower cortisol and, in turn, immune factors that would benefit from lower cortisol levels could be studied using this co-regulation model.

Touch aversion

Infants and children can be touch averse. For example, common lore suggests that children with autism respond negatively to touch. However, we have shown that children with autism benefit from massage by having fewer sleep problems (Escalona, Field, Singer-Strunk, Cullen, & Hartshorn, 2001; Field et al., 1997) and being less inattentive in the classroom (see Fig. 1). Touch defensiveness has also been observed in children with ADHD (attention deficit hyperactivity disorder) but, again, these children benefited from massage therapy by showing more “on task” behavior in the classroom (Field et al., 1998). Further research is needed to determine the types of touch that may be clinically meaningful for children with autism and ADHD. These could then be used, as could massage by parents, as supplemental stimulation that might not only improve self-regulation behaviors in these children but also enhance parent–child interactions and relationships.

Touch in social interaction

Touch can be used to convey different emotions, not unlike facial and vocal expressions (Elfenbein & Ambady, 2002). Although the communication of emotion via touch might facilitate social interactions, the public display of interpersonal touch appears to vary across cultures (Field, 2001).

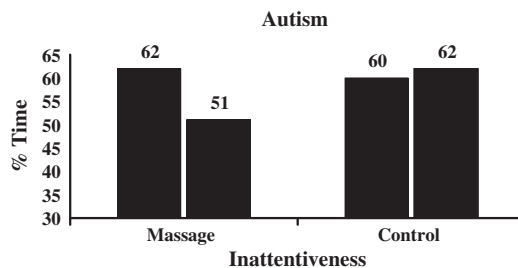


Fig. 1. Children with autism showing less inattentiveness (lower percent time observed) in classroom following a 1-month period of their parents massaging them 15 min daily before bedtime.

Touch can convey emotions

Recent studies have established that emotions can be identified from the simple experience of a stranger touching you on your arm without having any other cues from that person (Hertenstein, Holmes, & McCullough, 2009; Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006). In the Hertenstein et al. (2006) study, the investigators assigned a group of participants to the role of encoder (sender) who was instructed to express an emotion by touching the decoder's (receiver's) forearm. The sender was given different emotion words including happiness, sadness, surprise, disgust, anger, fear, sympathy, love, pride, envy and gratitude. The receiver was separated from the sender by a curtain to prevent any use of visual cues and was then asked to choose the emotion that was received from the sender. The results of this study showed that different kinds of touch were used to signal different emotions, and the receivers were able to identify the emotions, with accuracy ranging from 48% to 83%. This range is comparable to the accuracy of decoding facially and vocally transmitted emotions (Elfenbein & Ambady, 2002). Examples of these are that pushing, lifting and tapping were used to communicate disgust, and hitting, squeezing and trembling were used to communicate anger.

Even more emotions could be conveyed when the senders were allowed to touch any appropriate part of the human body to convey the emotion (Hertenstein et al., 2009). This led to a greater accuracy rate as well as the communication of a fuller repertoire of expressions including joy and sadness. These data are empirically interesting, but they have limited application for most interpersonal communications especially in low-touch societies like the US because of the taboos on touch and the litigious responses to violations of touch taboos.

Touch in personal relationships in different cultures

As was pointed out by Ashley Montagu in his book "Touching" (1971), "touch is ten times stronger than verbal or emotional contact, and it affects damn near everything we do. No other sense can arouse you like touch. We forget that touch is not only basic to our species, but the key to it." Despite the importance of touch for human communication and relationships, interpersonal touch is actively discouraged in the US, as already mentioned, because of potential child abuse or the threat of litigation (Field, 2001). Similarly low rates of touching have been noted in England. In a study on touch in cafes, couples in San Juan, Puerto Rico touched each other on average a hundred times an hour while those in London cafes averaged zero touches per hour (Jourard, 1966). More cross-cultural studies of this kind are needed so that we can be aware of cultural differences in touch and not misinterpret them. Even within country, across-ethnic-group studies would be informative. For example, a study comparing Cuban and Puerto Rican mother–infant interactions suggested less poking touch by the Puerto Rican mothers (Field & Widmayer, 1981), and infants were noted to prefer less poking touch. Quality of touch as well as touch quantity appear to affect early interactions between parents and their children.

In studies we have conducted comparing parents touching their preschool children in Miami versus Paris, the French parents were physically affectionate towards their children more often than the American parents. The French children showed less aggression than the American children (Field, 1999a). In comparisons made between adolescents at fast food restaurants in Paris versus those in Miami, the French adolescents touched each other more than the American adolescents who engaged in more self-touching/self-stimulation (e.g. fingering their hair and rubbing their arms) (Field, 1999b) (see Fig. 2). The French adolescents were also physically and verbally less aggressive than the American adolescents. These data are perhaps not surprising given that cultures that feature more physical affection towards their infants characteristically have less adult violence (for example, the Arapesh culture as opposed to the Mundugamor). And, monkeys who experience less touch by their peers because they are physically separated by a plexiglass wall are more aggressive following the separations (Suomi, 1984). Nonetheless, more studies are needed on the role of touch in interpersonal relationships across development and in different cultures.

Interpersonal touch is also affected by context. For example, higher rates of touching have been observed in airport departure and arrival lounges than in cafes (Greenbaum & Rosenfeld, 1980). In the airport setting, approximately 60% of individuals were noted to share some form of interpersonal touch. It is perhaps not surprising that more touch occurred in the airport setting because it is

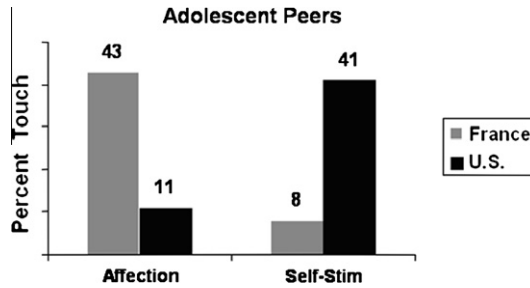


Fig. 2. Adolescents in France versus the US spent a greater percent time displaying physical affection (e.g. hugging) and a lower percent time displaying self stimulation (e.g. rubbing arms) during their interactions with peers.

typically closely-related people who are separated at airports. Also, it was not surprising that the greatest percentage of touch occurred among couples. The type of relationship also affects touching. For example, romantic relationships usually feature more touching than casual platonic relationships.

Touch and love have been called “indivisible” (Montagu, 1971). One of the five expressions of love is through physical touch (Goff, Goddard, Pointer, & Jackson, 2007). Several forms of romantic touch have been noted including holding hands, hugging, kissing, cuddling, caressing and massaging (Gulledge & Fischer-Lokou, 2003). In that study, the authors showed that physical affection was highly correlated with overall relationship and partner satisfaction (Gulledge & Fischer-Lokou, 2003). In fact, the absence of touch may prevent the development of a romantic relationship. Very little is known about the role of touch in the development and duration of romantic relationships.

Virtual reality touching devices

Several devices have recently been developed to provide tactile contact. For example, the “keep in touch” system was designed for couples to have physical intimacy across distances (Motamedi, 2007). This fabric touch screen presents a blurred image of each partner, and when the partner touches various parts of the body, the image is brought into focus. However, the “keep in touch” system was never tested for its effectiveness. Similarly, a number of hugging devices have been created. One is intended to provide an actual hug by a vest that inflates (Mulleler et al., 2005). Another “hug-shirt” has sensors that can detect the strength and the warmth of a hug as well as the heartrate of the hugger. These devices, unfortunately, have not been empirically tested. Some have also questioned their ability to ever replace real touch (Haans, Ijsselsteijn, Graus, & Salminen, 2008).

The skin's role in interpersonal touch

The skin itself plays a role in interpersonal touch. The smoothness and softness of the skin are perceived as pleasant (Guest et al., 2009). In the Guest et al. (2009) study, ratings were made of one's own skin and the skin of others. Surprisingly, in this study, one's own skin was rated as less pleasant than the skin of others. In their experiments, the pleasantness of touched skin was associated with the skin's perceived smoothness and softness and negative associations with its perceived stickiness (Guest et al., 2009). These authors suggested that their results were consistent with other research using inanimate surfaces (e.g. textiles and sandpaper). In a study on textures, skin conductance responses were consistent with facial expression responses to the different textures (Ramachandaran & Brang, 2008). Specific textures (e.g. denim, wax, sandpaper, silk) evoked distinct emotions (e.g. depression, embarrassment, relief and contentment respectively).

Friendly touching affects compliance

Several investigators have documented how positively people respond to touch in different situations. The participants or customers in these observational studies are typically more responsive to

requests if they are accompanied by friendly touch. People are more likely to give someone something if they are touched at the same time that the request is made (Joule & Gueguen, 2003). For example, when passengers touch a bus driver while requesting a free ride, they are more likely to get a free ride (Gueguen & Fischer-Lokou, 2003). And customers at car dealers assigned more positive ratings to the salesmen who touched them than the salesmen who did not touch them (Erseau & Gueguen, 2007). This phenomenon has also been demonstrated in the classroom. When a teacher asked students to demonstrate the solution to a math problem on a blackboard (Gueguen, 2004), more students volunteered to demonstrate the solution when they were touched by the teacher.

Interpersonal touch has also affected people's health. In a study on elderly individuals, more healthful food including more protein was consumed following touch (Eaton, Mitchell-Bonair, & Friedmann, 1989). These effects were noted to last as long as 5 days after the touching occurred. Many of these studies are, of course, confounded by other sensory stimulation such as visual and auditory stimulation during the touching condition. Although studies are needed to assess the independent effects of touch stimulation, it is perhaps not surprising that compliance might be greater during the more naturalistic multisensory stimulation.

Quantity of touch may also matter. For example, in at least one study, two touches were noted to be more effective than one (Vaidis & Halimi-Falkowicz, 2008). In this study, participants were asked to complete a questionnaire, and they were either touched once or twice or not at all by the experimenter. The results showed that there was more compliance in the two-touch than in the one-touch condition and more in the one-touch condition than not at all. These touch procedures led to more compliance irrespective of the length of the questionnaire, and touch was more effective when it was made by a female experimenter toward a male participant. This result is somewhat surprising given that earlier studies reported more positive effects of touching on female versus male patients (Whitcher & Fisher, 1979). Compliance is a complex phenomenon that may involve the subcortical regions that play a role in the perception and search for award or gratitude. These authors noted that conformity and compliance are mediated by self-esteem, popularity and acceptance. Award and gratitude may be two of many mediating cognitions that are stimulated by touch and may be involved in the compliance outcomes of touch. Further research is needed on this issue.

Neural bases for encoding touch

The right orbitofrontal cortex appears to be involved in encoding tactile information (Frey Law et al., 2008). Positron Emission Tomography has been used to measure brain activity related to the encoding of tactile stimuli. Cerebral blood flow during novel stimuli was compared to cerebral blood flow during aversive tactile stimuli. The right orbitofrontal cortex was involved in the act of encoding the novel tactile stimuli while the region of the orbitofrontal cortex that is more closely connected with limbic and autonomic regions of the brain was activated when the participants explored aversive tactile stimuli.

Another group of investigators compared brain activity following pleasant touch versus painful and neutral touch using Functional Magnetic Resonance Imaging (Rolls et al., 2003). Regions of the orbitofrontal cortex were less activated by neutral touch than by pleasant touch and by painful stimulation, suggesting that affective touch activates that region. Affective touch, both positive and negative, is not only represented in parts of the orbitofrontal cortex but also in the cingulate cortex (Rolls, 2008).

Further evidence of how the orbitofrontal cortex is involved in affective aspects of touch was that touch to the forearm (which has nerves that are sensitive to light touch) compared to touching the glabrous skin in the palm of the hand (which does not have nerves that are sensitive to light touch) activated the orbitofrontal cortex (McCabe, Rolls, Bilderbeck, & McGlone, 2008). Word labels as well as the sight of touch can activate that area, for example, using word labels such as "rich moisturizing cream" while cream was being applied to the forearm or as it was seen being applied to a forearm (McCabe et al., 2008). The cognitive labels influenced the activation as did the sight of touch and were also correlated with pleasantness.

Although it is not clear which part of the brain is activated by moderate pressure touch, moderate pressure massage appears to be therapeutic (Field, Diego, & Hernandez-Reif, 2010a, 2010b, 2010c). In

a study we conducted comparing different pressure massage, heart rate slowed and EEG patterns became more following moderate pressure massage versus light pressure massage (Diego, Field, Sanders, & Hernandez-Reif, 2004). However, light and moderate pressure touch have not been compared in social interactions.

Another region that has been implicated in affective touch is the insular cortex (Wessberg, Olausson, Fernstrom, & Vallbo, 2003). The insular cortex may also be involved in processing intermodal stimulation, although very little is currently known about the contribution of auditory and visual inputs to tactile stimulation (McCabe et al., 2008; Montoya & Sitges, 2006). At least one review suggests that tactile information interacts with information from other senses including visual, auditory and kinesthetic senses (Gallace & Spence, 2009). This is not surprising inasmuch as intermodal perception has been documented at least for touch and vision as early as the newborn period (Meltzoff & Borton, 1979). Given that most stimulation in the real world is intermodal, more research is needed on responses to intermodal stimulation and the role that touch plays in interaction with each of the different senses. fMRI methods would seemingly lend themselves to at least identifying regions or overlapping regions where the processing of intermodal stimulation occurs.

Not only different parts of the brain but different systems seem to differentiate affective from non-affective touch. For example, a recent study suggested that affiliative or affectionate touch is transmitted via unmyelinated (non-insulated) nerve fibers (McGlone, Vallbo, Olausson, Loken, & Wessberg, 2007). In contrast, the discriminative aspects of touch were conveyed by fast-conducting myelinated (insulated) nerve fibers. Thus, these two systems seem to have different biophysical, electrophysiological, neurobiological and anatomical properties.

How touch perception might substitute or compensate for other senses that are missing, for example, in blind and deaf individuals is also relatively unknown. Some studies were conducted mapping touch stimuli on the backs of blind people as a substitute vision experience (Bach-y-Rita, 2004). And, others developed tactile vocoders (belts that provided touch stimuli in the speech range) for deaf children (Ozdamar et al., 1992), but further research is needed in this area.

Physiological and biochemical effects of touch

Several studies have documented positive physiological and biochemical effects of touching including decreases in blood pressure and heart rate as well as decreased cortisol levels and increased oxytocin levels (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Henricson, Berglund, Maatta, Ekman, & Segesten, 2008). Decreased cortisol (stress hormone) and increased oxytocin (“love hormone” or hormone that increases following touch in both animals and humans) may be related, although they are rarely measured simultaneously in the same study.

Lower blood pressure and heart rate have been noted in people who received handholding and a 20-s hug from their partner prior to a stress condition (a public speaking condition) (Grewen, Anderson, Girdler, & Light, 2003). Couples engaged in handholding while viewing a 10-min romantic video which was then followed by the hug. However, the study was confounded by the multiple forms of stimulation, (i.e. talking and seeing the partner as well as watching the video). These confounds are difficult to separate, of course, without destroying the naturalistic situation.

In another study, women experienced different kinds of stimulation including neck and shoulder massage, verbal social support and a no partner contact group prior to experiencing a stress condition (Ditzen et al., 2007). The women who had the massage from their partner before the stress condition showed significantly lower heart rate responses and lower cortisol levels to the stress. As the authors suggested, these findings demonstrate a direct positive effect of touch on the physiology and biochemistry of women during a stressful condition. Surprisingly, the group who received verbal social support did not appear to benefit from that support.

In a study that measured both cortisol and oxytocin, touch was used as an intervention and compared to a behavior-monitoring control group over a 4-week intervention (Holt-Lunstad, Birmingham, & Light, 2008). Healthy married couples were randomly assigned to these groups and then monitored for salivary cortisol and alpha amylase, both biomarkers of stress. The intervention group’s husbands and wives relative to the controls showed enhanced salivary oxytocin and reduced alpha amylase both early and late in the intervention. The husbands in the intervention group also had lower

post-treatment 24-h systolic blood pressure than the control group. Other investigators have reported the release of oxytocin following physical affection such as back rubs and hugs (Shermer, 2004), and women who received more hugs from their partner showed higher oxytocin levels and lower blood pressure than women with fewer hugs in their history (Light, Grewen, & Amico, 2005). Thus, several laboratory studies have demonstrated the comforting effects of touch before and during stressors. These have been evident in the decrease of stress behaviors and stress hormones, for example, cortisol and alpha amylase. Unfortunately these findings have not been adopted into practice in hospitals, schools, and other settings where stress levels are high (e.g. pre-surgery and pre-testing situations). Further research is needed in lesser studied samples like children and adolescents, and mechanism studies would enhance our understanding of how touch, for example, lowers stress hormones.

Massage therapy effects

Massage therapy is one of the most effective forms of touch. It has been used primarily to treat pain, although it is increasingly used for other problems including job stress, depression, autoimmune conditions like asthma, dermatitis and diabetes and immune conditions, most especially cancer (see Field, Diego, & Hernandez-Reif, 2006 for a review).

Massage therapy reduces pain

In cancer patients, massage has been notably effective for both immediate pain and mood (Kutner et al., 2008). In the Kutner et al. (2008) study, adults with advanced cancer who were experiencing moderate-to-severe pain and enrolled in hospice received six sets of 30-min massages or simple-touch sessions over a 2-week period. Massage was more effective for both immediate pain and mood. In a review on massage therapy and cancer care, the authors noted that some large cancer centers in the US have started to integrate massage therapy into their programs based on the positive effects of massage on cancer pain (Russell, Sumler, Beinhorn, & Frenkel, 2008).

Massage therapy studies on pain in our lab have resulted in reduced pain in all chronic pain conditions from lower back pain in pregnancy to labor pain, back pain, migraine headaches, fibromyalgia and juvenile rheumatoid arthritis (see Field et al., 2006 for a review). Massage therapy has also been provided for children and adolescents who were admitted to a chronic pediatric pain clinic (Suresh, Wang, Porfyrus, Kamasinski-Sol, & Steninhorn, 2008). After the therapy sessions, the children and adolescents reported significantly lower levels of pain, discomfort and depressed mood. In a study on postoperative pain management, back massages resulted in decreased pain intensity as well as lower anxiety levels (Mitchinson et al., 2007).

Although most of the massage therapy studies have been conducted on patients in clinical settings, some laboratory research has also been performed to determine its effects on pain. For example, one group studied the effects of massage on mechanical hyperalgesia (pressure pain thresholds) and perceived pain using delayed onset muscle soreness as a model for myalgia (Frey Law et al., 2008). The participants were assigned to a deep-tissue massage group, a superficial touch group or a no-treatment control group. Exercises were then performed to induce delayed onset muscle soreness. The deep massage decreased pain by 48% during the muscle stretch.

Potential underlying mechanisms for massage reducing pain

The mechanism that has been most frequently used to explain massage therapy effects on pain syndromes is the Gate Theory (see Field et al., 2006 for a review). According to that theory, pain stimulates shorter and less myelinated (or less insulated) nerve fibers so that the pain signal takes longer to reach the brain than the pressure signal which is carried by nerve fibers that are more insulated and longer and therefore able to transmit the stimulus faster. The message from the pressure stimulation reaches the brain prior to the pain message and “closes the gate” to the pain stimulus. This metaphor for the electrical and chemical changes that likely occur has been commonly used to explain the pain-reducing effect of grabbing your crazy bone when it has been bumped.

Another theory that is commonly referenced is the deep sleep theory. In deep sleep, less substance P (a pain chemical) is emitted and therefore less pain occurs because substance P causes pain. We directly tested the “enhanced deep sleep leading to less substance P” theory in our study on fibromyalgia (Field et al., 2002). Following a period of massage therapy, more time was spent in deep sleep, and lower levels of substance P were noted in the saliva samples taken (see Fig. 3).

Still another theory is that less pain results from increased levels of serotonin (Field et al., 2002), serotonin being the body’s natural anti-pain chemical. Serotonin also decreases cortisol and depression which are also important effects of massage therapy. And, serotonin is also noted to decrease substance P and other pain-causing chemicals, highlighting the complex interaction between massage therapy’s effects on biochemistry. Further research is needed to test these models. As in medicine, in general, underlying mechanism research advances the field both by expanding the knowledge base and by enhancing credibility for a wider adoption of therapies like massage. One of the basic research problems for hands-on therapies like massage is the ethical problem of random assignment to a no-treatment control group when a treatment is known to be effective as well as the inability to double-blind the study so that the treatment is unknown to the research participants.

Massage therapy enhances attentiveness

Massage therapy has also enhanced attentiveness. In a laboratory study by our group, 15-min chair massages led to heightened alertness/attentiveness (Field et al., 1996). This was evidenced by an EEG pattern of heightened alertness/attentiveness that included increased beta and theta waves and decreased delta waves. This EEG pattern of alertness/attentiveness following the massage sessions was accompanied by improved performance on math computations including being able to perform them in less time with greater accuracy.

The effects of massage on attentiveness might also be mediated by increased vagal activity. Stimulation of the vagus (the 10th cranial nerve) leads to greater attentiveness. The vagus nerve has a branch to the heart and effectively slows heart rate (Porges, 2001). In many studies, increased vagal activity has been accompanied by decreased heart rate, and increased attentiveness is typically associated with decreased heart rate (see Field & Diego, 2008a, 2008b for a review). Moderate pressure massage (versus light pressure massage) which would stimulate pressure receptors is significantly associated with enhanced attentiveness, including slower heart rate and EEG patterns associated with enhanced attentiveness (Diego et al., 2004). Stimulation of pressure receptors increases vagal activity which, in turn, should enhance attentiveness. This might also explain the enhanced attentiveness following massage therapy in children with autism and adolescents with HIV (see Field et al., 2006). More laboratory controlled studies are needed to further explore potential underlying mechanisms for massage therapy enhancing attentiveness.

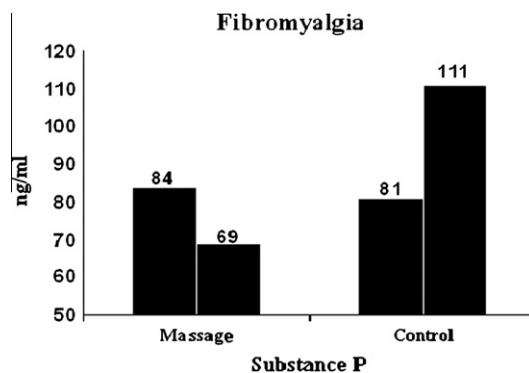


Fig. 3. Substance P (a pain chemical measured in saliva in ng/ml) decreases following massage as apposed to a waitlist control.

Massage therapy reduces depression and modifies EEG and other correlates

Massage therapy has also been effective in reducing depression. In depressed individuals EEG is typically more activated on the right side of the frontal region of the brain versus the left side (Henriques & Davidson, 1991). EEG asymmetry, specifically greater relative right frontal EEG activation, is associated with negative affect. Chronically depressed individuals show stable patterns of this asymmetry. Previously depressed adults, for example, show greater relative right frontal EEG activation even when they are in remission or no longer showing behavioral symptoms (Henriques & Davidson, 1991). This suggests that right frontal EEG is a physiological marker for depression, independent of depressed behavior. Frontal EEG typically shifts from right to left in depressed adolescents (Jones & Field, 1999) and adults following massage therapy (Field & Diego, 2008a, 2008b).

During massage treatments, EEG has been noted to shift for depressed individuals from the right to the left side, which is a positive shift since greater relative left frontal EEG is associated with positive, approach emotions like happiness (Field & Diego, 2008a, 2008b). Massage has been noted to shift from predominantly right frontal EEG activity to symmetry (to the center) or towards the left frontal region (a positive shift in EEG). Other correlates of depression have also changed following massage therapy. These include an increase in vagal activity that is typically lower in depressed individuals (Field et al., 2004). Low vagal activity would explain the flat affect (facial expressions and intonation contour) noted in the faces and voices of depressed people inasmuch as the vagus nerve (one of the 12 cranial nerves) stimulates the face and voice muscles (Porges, 2001).

Neurohormonal/neurotransmitter correlates of depression in depressed individuals have also been affected by massage therapy. Cortisol (stress hormone) levels that are typically high in depression have decreased following massage therapy (Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005) as have norepinephrine (stress neurotransmitter) levels (Field et al., 1992). In contrast, serotonin (the brain's natural antidepressant) levels have increased following massage therapy (Field et al., 2005). There are, of course, other correlates that could be affected including a reduction in inflammatory cytokines (immune cells) that would help explain the decrease in illness related to massage.

Massage therapy enhances immune function

Children with cancer have been noted to benefit from massage therapy (Post-White et al., 2009). After four weekly massage sessions alternating with four weekly quiet-time control sessions, massage was more effective at reducing heart rate and anxiety levels in the children. The parents conducted the massages, and they also reported less anxiety following the sessions.

In several studies natural killer cells and natural killer cell activity have increased following massage therapy (Field et al., 2006). This finding suggests improved immune function, given that natural killer cells are the front line of the immune system, warding off viral cells, bacterial cells and cancer cells. In a study on HIV infected adolescents, we showed that natural killer cells increased following a 1-month period of massage (Diego, Hernandez-Reif, Field, Friedman, & Shaw, 2001). This suggested a better clinical course inasmuch as natural killer cells have been thought to substitute for CD4 cells (the cells that are destroyed by the HIV virus). The CD4 cells also increased in the adolescents, suggesting an improved clinical condition. In addition, in our studies on breast cancer, natural killer cells and natural killer cell cytotoxicity (activity) increased, again suggesting improved immune function (Hernandez-Reif et al., 2004, 2005). The clinical condition of these women would be expected to improve inasmuch as natural killer cells are known to destroy tumor cells (Brittenden, Heys, Ross, & Eremin, 1996). Stimulation of pressure receptors via massage therapy might be the underlying mechanism for the increased natural killer cells. Stimulation of pressure receptors, as in the friction and stroking of massage, may increase parasympathetic activity (vagal tone), which would be expected to reduce cortisol levels and thereby enhance immune function (Diego et al., 2004).

The underlying mechanisms for improved immune function following massage therapy are not clearly established, although like most biological phenomena they would be complex. Cortisol is noted to kill immune cells, and natural killer cells are noted to kill bacterial, viral and cancer cells. However, these relationships are likely confounded by other variables, and other immune functions such as pro-inflammatory immune cells (cytokines) may also be involved. At this time invasive blood sampling

would be necessary for these assays, making this research difficult to conduct both for technical and ethical reasons.

Moderate pressure is necessary

Moderate pressure seems to be necessary for massage therapy to effectively lead to the cascade of events that results in increased vagal activity and all its effects already discussed (Diego et al., 2004). Because the therapeutic effects are related to moderate pressure massage, we have been using light pressure massage therapy as a sham comparison group. The light pressure group receives exactly the same massage as the moderate pressure group except that lighter pressure is applied. Our findings that moderate versus light pressure massage is effective suggest involvement of pressure receptors. Animal studies indicate that pressure receptor stimulation activates the vagus nerve (Pauk, Kuhn, Field, & Schanberg, 1986; Schanberg & Field, 1987). Further, as already mentioned, in our study on the immediate effects of light pressure versus moderate pressure massage, we showed that lower heart rate and EEG patterns of lower arousal were associated with moderate versus light pressure massage (Diego et al., 2004). Long-term effects have also been demonstrated including better neonatal outcomes (less prematurity and low birthweight) following the use of moderate pressure massage during pregnancy (Field et al., 2010). In addition, infants who received moderate versus light pressure massage from their mothers gained more weight and had better development over the first months of life (Field, Diego, Hernandez-Reif, Deeds, & Figuereido, 2006).

Massage therapy increases vagal activity

Vagal tone increases immediately after massage therapy sessions and across repeated sessions of massage therapy (Diego et al., 2004, 2007). In these studies, significant increases in vagal activity occurred following massage therapy. This likely happens via the stimulation of dermal and subdermal pressure receptors that are innervated by vagal afferent fibers, which ultimately project to the limbic system in the brain including hypothalamic structures involved in autonomic nervous system regulation and cortisol secretion.

These pathways are supported by several lines of evidence. First, anatomical studies indicate that baroreceptors, and to a lesser extent, mechanoreceptors within and beneath the skin (i.e. Pacinian corpuscles) transmit signals to the vagal nucleus of the solitary tract, the predominant source of afferent inputs to the efferent neurons of the nucleus ambiguus and the dorsal motor nucleus of the vagus (Kandel, Schwartz, & Jessell, 2000). Second, functional studies indicate that electrical vagal stimulation reduced cortisol levels in depressed individuals (O'Keane, Dinan, Scott, & Corcoran, 2005). Third, as already noted, we recently showed that moderate pressure massage (but not light pressure massage) increased vagal activity in both infants and adults (see Field & Diego, 2008a, 2008b for a review). Fourth, data collected across several studies by our group and others indicated that massage therapy decreased heart rate (Diego et al., 2004; Kubsch, Neveau, & Vandertie, 2000), lowered blood pressure (Ahles et al., 1999; Hernandez-Reif, Field, Krasnegor, & Burman, 2000; Kubsch et al., 2000) and reduced cortisol levels (see Field et al., 2005 for a review; Kim, Cho, Woo, & Kim, 2001). And fifth, a recent fMRI study revealed that massage therapy increased cerebral blood flow across several brain regions involved in depression and stress regulation including the amygdala and the hypothalamus (Ouchi et al., 2006), suggesting that massage therapy involves hypothalamic regulation of autonomic nervous system activity, cortisol secretion and limbic activity associated with emotion regulation.

Vagal activity may mediate the effects of massage on cortisol

Increased vagal activity which represents parasympathetic activation results in a slowing of physiology (decreased heart rate and blood pressure) and down-regulation of cortisol (Porges, 2001). Psychological stressors that reduce vagal activity have been noted to increase cortisol (Spangler, 1997). Others have interpreted this relationship as vagal activity playing an inhibitory function on hypothalamic pituitary adrenal function (Thayer & Sternberg, 2006). As Thayer and Sternberg (2006) noted, the prefrontal cortex and amygdala are important central nervous system structures linked to the

regulation of emotion and hypothalamic pituitary adrenal (HPA) axis function. Other biochemical changes have occurred following massage therapy that might be mediated via increased vagal activity including the reduction of norepinephrine (a stress neurotransmitter) and increased serotonin (the brain's natural antidepressant and anti-pain chemical) and dopamine (an activating neurotransmitter) (Field et al., 2005). How these changes interact with cortisol reduction and other biochemical changes that have not yet been measured warrants further research. As assay technology advances are made, additional biochemical changes can be measured noninvasively such as in saliva sampling.

Preterm infant massage research as a model for exploring potential underlying mechanisms

In many neonatal intensive care units around the world, preterm infant massage has been noted to increase weight gain (see Field et al., 2010a, 2010b, 2010c for a review). In a series of studies we explored potential underlying mechanisms for massage therapy increasing preterm infant weight gain. In the first of these, preterm infant weight gain following massage therapy was related to increased vagal activity and gastric motility which may have contributed to more efficient food absorption (Ditzen et al., 2007). In a subsequent study, preterm neonates were randomly assigned again to a moderate pressure massage group for three, 15-min periods per day for 5 days or a control group who received standard nursery care without massage therapy (Field et al., 2008). The massaged preterm infants showed greater increases during the 5-day treatment period in: (1) weight gain; (2) serum levels of insulin; and (3) IGF-1 (a growth factor). Increased weight gain was significantly correlated with insulin and IGF-1 levels. Thus, these data suggest that weight gain was also related to increased serum insulin and IGF-1 levels following massage therapy.

Another potential underlying mechanism is the increased temperature noted in preterm infants during massage therapy, decreased temperature being associated with energy expenditure that could result in weight loss. In this study, temperature was assessed in 72 preterm infants randomly assigned to a control or moderate pressure massage group (Diego, Field, & Hernandez-Reif, 2008). A greater increase in temperature was noted in the preterm infants receiving massage therapy, even though the incubator portholes remained open during the 15-min massage therapy sessions (which would be expected to lower their temperature).

Another group explored the potential underlying mechanism of reduced energy expenditure in preterm neonates receiving massage (Lahat, Mimouni, Ashbel, & Dollberg, 2007). During the treatment period, the same massage therapy protocol as used in our preterm infant studies was provided. Metabolic measurements were performed by direct calorimetry by a metabolic cart. Energy expenditure was significantly lower in infants after the 5-day massage therapy period than after the period without massage. This decreased energy expenditure may be in part responsible for the enhanced growth associated with massage therapy.

Preterm infants receiving moderate pressure massage may also be showing fewer stress behaviors, as was noted in a study by our group (Field et al., 2006). The moderate versus light pressure massage group gained significantly more weight per day, and during the behavior observations, the moderate pressure massage group showed significantly lower increases in: (1) active sleep; (2) fussing; (3) crying; (4) movement; and (5) stress behavior (hiccupping). They also showed a smaller decrease in deep sleep, a greater decrease in heart rate and a greater increase in vagal tone. All of these changes suggest a decrease in general arousal, which, in turn, may explain improved immune function in preterm neonates. In a study in which mothers massaged their infants on the face and limbs as well as passively exercised their upper and lower limbs four times a day, the incidence of delayed-onset sepsis was significantly lower in the intervention group (Mendes & Prociyanoy, 2008). The massage group also had a shorter hospital stay by 7 days, probably related to their lesser illness.

A future study would desirably include the measures from both these studies to assess the potential mechanisms pathway of massage increasing vagal activity, in turn decreasing cortisol, enhancing immune function and reducing sepsis. Inflated pro-inflammatory cytokines such as IL-1, IL-6 and TNF-alpha should also be measured for their contribution to sepsis and their potential reduction by massage therapy. In addition, the mothers who conducted the massages should be assessed for the positive effects they experienced. As already noted, the massager can experience similar benefits. Although human touch/massage would likely be more effective than other forms of stimulation,

exercises like yoga may be a form of self-massage. Rubbing limbs against each other or against the floor may simulate the effects of massage. Pilot data from our lab suggest that prenatal yoga like pregnancy massage may reduce lower back and leg pain and decrease cortisol levels (Field et al., 2010a, 2010b, 2010c). Massaging devices might also be effective, although they would probably be less effective than human massage.

Summary, conclusions, implications and future directions

This review briefly summarizes recent empirical research on touch. The research includes the role of touch in early development, touch deprivation, touch aversion, emotions that can be conveyed by touch, the importance of touch for interpersonal relationships and how friendly touch affects compliance in different situations. fMRI data are reviewed showing activation of the orbitofrontal cortex and the caudate cortex during affective touch which appears to be transmitted via unmyelinated C afferents. Physiological and biochemical effects of touch are also reviewed including decreased heart rate, blood pressure and cortisol and increased oxytocin. Similar changes noted following moderate pressure massage appear to be mediated by the stimulation of pressure receptors and increased vagal activity. Increased serotonin and decreased substance P may explain its pain-alleviating effects. Positive shifts in frontal EEG also accompany moderate pressure massage along with increased attentiveness, decreased depression and enhanced immune function including increased natural killer cells, making massage therapy one of the most effective forms of touch.

Although great strides have been made on the science of touch, it still seems “the neglected sense” relative to the other senses. Many developmental questions have not yet been addressed as they have for the other senses. For example, very little research has been conducted on changes in touch sensory thresholds with age. In contrast, taste and smell thresholds are reputed to increase with age such that more subtle tastes and smells are not as discernible with aging. Very little is also known about touch sensory thresholds at the younger end of the age continuum relative to the visual and auditory senses. In part this may relate to the other senses being more easily measured than touch.

Several touch phenomena have been established in laboratory studies, but the applications to real life situations are less known. For example, as we have noted, different kinds of touch convey different emotions. But the mandates against touch, for example in the US, suggest that emotions will continue to be expressed in the vocal and facial modalities rather than through touch. And, as another example, while we know from a few laboratory studies that partners’ holding hands and hugging lessens negative responses to stressors, it is not clear how often those comforting forms of touch occur in naturalistic situations except from the observational study on airport departures. The laboratory studies are informative, but they would be complemented by naturalistic studies.

Although touch is thought to be vital to social interactions, at least in intimate relationships, we also know very little about touch in intimate relationships and across development. We know from laboratory studies that infants prefer stroking to tickling and moderate to light pressure massage. We know from daycare studies that children receive less touch as they move from the infant to toddler to preschool years. And, based on playground observation studies we have reported that American children receive less touch than French children. However, we do not know how much or what types of touch infants and children receive from their parents at home, and we know even less about how much parents touch each other and if their touching each other is reduced as they parent their children. Grandparent-age people may not receive enough touch after they lose their partners. They may benefit from touching others, as in volunteer daycare and hospital positions, not unlike their benefitting from massaging infants (Field, Hernandez-Reif, Quintino, Schanberg, & Kuhn, 1998).

The degree to which touch facilitates and sustains relationships is another important area of research. Couples who touch each other more might be expected to fight less, have greater intimacy and longer-lasting relationships. And touch sensitivity or aversion to touch in one partner, especially if the other partner likes touching, might be disruptive to their relationship. Although a touch sensitivity scale has appeared in the literature, very little is known about individual differences in touch sensitivity and touch aversiveness. Parents who massage their children might be expected to be less neglectful, and children who are more physically affectionate would be expected to have more physically affectionate parents in response to them.

Touch deprivation has been noted to have negative effects on cognitive development, although those data came from extreme deprivation situations such as the Romanian orphanages. Very little is known about the effects of lesser deprivations. “No touch” mandates exist in public schools across the US but virtually no research has been done on the effects of that touch deprivation except leaps from animal data suggesting that the increasing violence in the school system may be related to the touch deprivation. Less touch between peers in this internet age may also be a factor. What happens to internet relationships without touch? Do single adults deprived of touch experience more illness as a flip side to adults with pets reputedly having lower blood pressure and less chronic illness? It is likely that the immune system is compromised by touch deprivation inasmuch as massage has been noted to lower cortisol levels and in turn save natural killer cells. Again, hearing loss and loss of vision have been easier to investigate and more often researched than the loss of touch. We cannot experiment with these variables on humans or animals. We are limited to observational studies and supplemental touch studies such as the handholding and hugging prior to a stressor study. That study is seemingly a good scientific and ethical model for assessing touch effects on physiological and biochemical measures.

Although the technology for measuring the effects of touch has become more sophisticated, for example, fMRIs indicating activation in different parts of the brain, it is not clear that knowing precisely which part of the brain is activated tells us much about the physiological/biochemical processes that affect our emotional and physical well-being. And, although heart rate and blood pressure can indicate arousal, it is sometimes unclear whether that is a positive or negative state. Nonetheless, heart rate, blood pressure and saliva cortisol and immune factor changes are non-invasive, cost-effective measures that help inform underlying mechanism and intervention models such as the massage therapy research.

Thus, the rapidly increasing literature on touch and massage therapy highlights the need for touch for social-emotional and physical development and well-being and the therapeutic benefits of massage. Additional research is needed, however, to explore developmental changes as well as long-term effects and potential underlying mechanisms for these effects. Further laboratory and observational studies are needed to document the effects of touch on relationships. Clinical research trials are needed on how to reintroduce touch, for example, into school systems and massage therapy into hospitals and generally eliminate the taboos in our society against touch, making good touch replace the bad touch that led to the mandates against touch.

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References

- Ahles, T. A., Tope, D. M., Pinkson, B., Walch, S., Hann, D., Whedon, M., et al (1999). Massage therapy for patients undergoing autologous bone marrow transplantation. *The Journal of Pain and Symptom Management*, *18*, 157–163.
- Bach-y-Rita, P. (2004). Tactile sensory substitution studies. *Annals of the New York Academy of Science*, *1013*, 83–91.
- Beckett, C., Maughan, B., Rutter, M., Castle, J., Colvert, E., Groothues, C., et al (2006). Do the effects of early severe deprivation on cognition persist into early adolescence? Findings from the English and Romanian adoptees study. *Child Development*, *77*, 696–711.
- Belliemi, C. V., Cordelli, D. M., Marchi, S., Ceccarelli, S., Perrone, S., Maffei, M., et al (2007). Sensorial saturation for neonatal analgesia. *Clinical Journal of Pain*, *23*, 219–221.
- Brittenden, J., Heys, S., Ross, J., & Eremin, O. (1996). Natural killer cells and cancer. *American Cancer Society*, *77*, 1226–1243.
- Chugani, H. T., Behen, M. E., Muzik, O., Juhasz, C., Nagy, F., & Chugani, D. C. (2001). Local brain functional activity following early deprivation: A study of postinstitutionalized Romanian orphans. *Neuroimage*, *14*, 1290–1301.
- Corbetta, D., & Snapp-Childs, W. (2009). Seeing and touching: The role of sensory-motor experience on the development of infant reaching. *Infant Behavior and Development*, *32*, 44–58.
- Diego, M., Field, T., & Hernandez-Reif, M. (2008). Temperature increases in preterm infants during massage therapy. *Infant Behavior and Development*, *31*, 149–152.
- Diego, M., Field, T., Hernandez-Reif, M., Deeds, O., Ascencio, A., & Begert, G. (2007). Preterm infant massage elicits consistent increases in vagal activity and gastric motility that are associated with greater weight gain. *Acta Paediatrica*, *96*, 1588–1591.

- Diego, M. A., Field, T., Sanders, C., & Hernandez-Reif, M. (2004). Massage therapy of moderate and light pressure and vibrator effects on EEG and heart rate. *International Journal of Neuroscience*, *114*, 31–45.
- Diego, M. A., Hernandez-Reif, M., Field, T., Friedman, L., & Shaw, K. (2001). HIV adolescents show improved immune function following massage therapy. *International Journal of Neuroscience*, *106*, 35–45.
- Dieter, J., Field, T., Hernandez-Reif, M., Emory, E. K., & Redzepi, M. (2003). Stable preterm infants gain more weight and sleep less after five days of massage. *Journal of Pediatric Psychology*, *28*, 403–411.
- Ditzen, B., Neumann, I. D., Bodenmann, G., von Dawans, B., Tuner, R. A., Ehlert, U., et al (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in woman. *Psychoneuroendocrinology*, *32*, 565–574.
- Eaton, M., Mitchell-Bonair, I. L., & Friedmann, E. (1989). The effect of touch on nutritional intake of chronic organic brain syndrome patients. *Journal of Gerontology*, *41*, 611–616.
- Elfenbein, H. A., & Ambady, N. (2002). Is there an ingroup advantage in emotion recognition? *Psychological Bulletin*, *128*, 243–249.
- Erceau, D., & Gueguen, N. (2007). Tactile contact and evaluation of the toucher. *Social Psychology*, *147*, 441–444.
- Escalona, A., Field, T., Singer-Strunk, R., Cullen, C., & Hartshorn, K. (2001). Brief report: Improvements in the behavior of children with autism following massage therapy. *Journal of Autism and Developmental Disorders*, *31*, 513–516.
- Ferber, S. G., Feldman, R., & Makhoul, I. R. (2008). The development of maternal touch across the first year of life. *Early Human Development*, *84*, 363–370.
- Field, T. (1999a). Preschoolers in America are touched less and are more aggressive than preschoolers in France. *Early Child Development and Care*, *151*, 11–17.
- Field, T. (1999b). American adolescents touch each other less and are more aggressive toward their peers as compared with French adolescents. *Adolescence*, *34*, 753–758.
- Field, T. (2001). *Touch*. Cambridge, MA: MIT Press.
- Field, T., & Diego, M. (2008a). Maternal depression effects on infant frontal EEG asymmetry. *International Journal of Neuroscience*, *118*, 1081–1108.
- Field, T., & Diego, M. (2008b). Vagal activity, early growth and emotional development. *Infant Behavior and Development*, *31*, 361–373.
- Field, T., Diego, M., Cullen, C., Hernandez-Reif, M., Sunshine, W., & Douglas, S. (2002). Fibromyalgia pain and substance P decrease and sleep improves after massage therapy. *Journal of Clinical Rheumatology*, *8*, 72–76.
- Field, T., Diego, M., Dieter, J., Hernandez-Reif, M., Schanberg, S., Kuhn, C., et al (2004). Prenatal depression effects on the fetus and the newborn. *Infant Behavior and Development*, *27*, 216–229.
- Field, T., Diego, M., & Hernandez-Reif, M. (2006). Massage therapy research. *Developmental Review*, *27*, 75–89.
- Field, T., Diego, M., & Hernandez-Reif, M. (2010a). Moderate pressure is essential for massage therapy effects. *International Journal of Neuroscience*, *120*, 381–385.
- Field, T., Diego, M., & Hernandez-Reif, M. (2010b). Preterm infant massage therapy research: A review. *Infant Behavior and Development*, *33*, 115–124.
- Field, T., Diego, M., & Hernandez-Reif, M. (2010c). Tai chi/yoga effects on anxiety, heartrate, EEG and math computations. *Complementary Therapies in Clinical Practice*, *16*, 235–238.
- Field, T., Diego, M., Hernandez-Reif, M., Deeds, O., & Figueiredo, B. (2010). Pregnancy massage reduces prematurity, low birthweight and postpartum depression. *Infant Behavior and Development*, *32*, 454–460.
- Field, T., Diego, M., Hernandez-Reif, M., Deeds, O., & Figueiredo, B. (2006). Moderate versus light pressure massage therapy leads to greater weight gain in preterm infants. *Infant Behavior and Development*, *29*, 574–578.
- Field, T., Diego, M., Hernandez-Reif, M., Dieter, J., Kumar, A., Schanberg, S., et al (2008). Insulin and insulin-like growth factor I (IGF-1) Increase in preterm infants following massage therapy. *Journal of Developmental and Behavioral Pediatrics*, *29*, 463–466.
- Field, T., Grizzle, N., Scafidi, F., Abrams, S., Richardson, S., Kuhn, C., et al (1996). Massage therapy for infants of depressed mothers. *Infant Behavior and Development*, *19*, 107–112.
- Field, T., Harding, J., Soliday, B., Lasko, D., Gonzalez, N., & Valdeon, C. (1994). Touching in infant, toddler and preschool nurseries. *Early Child Development and Care*, *98*, 113–120.
- Field, T., Harding, J., Yando, R., Gonzalez, K., Lasko, D., Bendell, D., et al (1998). Feelings and attitudes of gifted students. *Adolescence*, *33*, 331–342.
- Field, T., Hernandez-Reif, M., & Diego, M. (2010). Depressed mothers' newborns are less responsive to animate and inanimate stimuli. *Infant and Child Development* (Epub ahead of print).
- Field, T., Hernandez-Reif, M., Diego, M., Schanberg, S., & Kuhn, C. (2005). Cortisol decreases and serotonin and dopamine increase following massage therapy. *International Journal of Neuroscience*, *115*, 1397–1413.
- Field, T., Hernandez-Reif, M., Quintino, O., Schanberg, S., & Kuhn, C. (1998). Elder retired volunteers benefit from giving massage therapy to infants. *Journal of Applied Gerontology*, *17*, 229–239.
- Field, T., Ironson, G., Scafidi, F., Nawrocki, T., Goncalves, A., Burman, I., et al (1996). Massage therapy reduces anxiety and enhances EEG pattern of alertness and math computations. *International Journal of Neuroscience*, *86*, 197–205.
- Field, T., Lasko, D., Mundy, P., Henteleff, T., Kabot, S., Talpins, S., et al (1997). Brief report: Autistic children's attentiveness and responsivity improved after touch therapy. *Journal of Autism and Developmental Disorders*, *27*, 333–338.
- Field, T., Morrow, C., Valdeon, C., Larson, S., Kuhn, C., & Schanberg, S. (1992). Massage reduces anxiety in child and adolescent psychiatric patients. *Journal of the American Academy of Child and Adolescent Psychiatry*, *31*, 125–131.
- Field, T., & Widmayer, S. (1981). Mother–infant interactions among lower SES Black, Cuban, Puerto Rican and South American immigrants. In T. Field, A. Sostek, P. Vietze, & A. H. Leiderman (Eds.), *Culture and early interactions*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Frey Law, L. A., Evens, S., Knudtson, J., Nus, S., Scholl, K., et al (2008). Massage reduces pain perception and hyperalgesia in experimental muscle pain: A randomized, controlled trial. *Journal of Pain*, *9*, 714–721.
- Gallace, A., & Spence, C. (2009). The cognitive and neural correlates of tactile memory. *Psychological Bulletin*, *135*, 380–406.
- Goff, B. G., Goddard, H. W., Pointer, L., & Jackson, G. B. (2007). Measures of expression of love. *Psychological Reports*, *101*, 357–360.

- Goldstein-Ferber, S. (2004). Massage therapy and sleep–wake rhythms in the neonate. In T. Field (Ed.), *Touch and massage in early child development* (pp. 183–189). New Jersey: Johnson & Johnson Pediatric Institute.
- Greenbaum, P. E., & Rosenfeld, H. W. (1980). Varieties of touching in greeting: Sequential structure and sex-related differences. *Journal of Nonverbal Behavior*, 5, 13–25.
- Grewen, K. M., Anderson, B. J., Girdler, S. S., & Light, K. C. (2003). Nonverbal encouragement of participation in a course: The effect of touching. *Social Psychology of Education*, 7, 89–98.
- Gueguen, N. (2004). Nonverbal encouragement of participation in a course: The effect of touching. *Social Psychology of Education*, 7, 89–98.
- Gueguen, N., & Fischer-Lokou, J. (2003). Another evaluation of touch and helping behavior. *Psychological Reports*, 92, 62–64.
- Guest, S., Essick, G., Dessirier, J. M., Blot, K., Lopetcharat, K., & McGlone, F. (2009). Sensory and affective judgments of skin during inter- and intrapersonal touch. *Acta Psychologica Amsterdam*, 130, 115–126.
- Gulledge, N., & Fischer-Lokou, J. (2003). Another evaluation of touch and helping behaviour. *Psychological Reports*, 92, 62–64.
- Haans, A., IJsselstein, W. A., Graus, M. P., & Salminen, J. A. (2008). *The virtual midas touch: Helping behavior after a mediated social touch. Extended abstracts of CHI2008*. New York: ACM Press. pp. 3507–3512.
- Heinrichs, M., Baumgartner, T., Kirschbaum, C., & Ehler, U. (2003). Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. *Biological Psychiatry*, 54, 1389–1398.
- Henricson, M., Berglund, A. L., Maatta, S., Ekman, R., & Segesten, K. (2008). The outcome of tactile touch on oxytocin in intensive care patients: A randomized controlled trial. *Journal of Clinical Nursing*, 17, 2624–2633.
- Henriques, J., & Davidson, R. (1991). Left frontal hypoactivation in depression. *Journal of Abnormal Psychology*, 100, 535–545.
- Hernandez-Reif, M., Field, T., & Diego, M. (2004). Differential sucking by neonates of depressed versus non-depressed mothers. *Infant Behavior and Development*, 27, 465–476.
- Hernandez-Reif, M., Field, T., Diego, M., & Largie, S. (2002). Weight perception by newborns of depressed versus non-depressed mothers. *Infant Behavior and Development*, 24, 305–316.
- Hernandez-Reif, M., Field, T., Diego, M., & Largie, S. (2003). Haptic habituation to temperature is slower in newborns of depressed mothers. *Infancy*, 4, 47–63.
- Hernandez-Reif, M., Field, T., Ironson, G., Beutler, J., Vera, Y., Hurley, J., et al (2005). Natural killer cells and lymphocytes are increased in women with breast cancer following massage therapy. *International Journal of Neuroscience*, 115, 495–510.
- Hernandez-Reif, M., Field, T., Krasnegor, J., & Burman, I. (2000). High blood pressure and associated symptoms were reduced by massage therapy. *Journal of Bodywork and Movement Therapies*, 4, 31–38.
- Hernandez-Reif, M., Ironson, G., Field, T., Katz, G., Diego, M., Weiss, S., et al (2004). Breast cancer patients have improved immune functions following massage therapy. *Journal of Psychosomatic Research*, 57, 45–52.
- Herrera, E., Reissland, N., & Shepherd, J. (2004). Maternal touch and maternal child-directed speech: Effects of depressed mood in the postnatal period. *Journal of Affective Disorders*, 81, 29–39.
- Hertenstein, M. J., Holmes, R., & McCullough, M. (2009). The communication of emotion via touch. *American Psychological Association*, 9, 566–573.
- Hertenstein, M. J., Keltner, D., App, B., Bulleit & Jaskolka, A. R. (2006). Touch communicates distinct emotions. *Emotion*, 6, 528–533.
- Holt-Lunstad, J., Birmingham, W. A., & Light, K. C. (2008). Influence of a “warm touch” support enhancement intervention among married couples on ambulatory blood pressure, oxytocin, alpha amylase, and cortisol. *Psychosomatic Medicine*, 70, 976–985.
- Jones, N., & Field, T. (1999). Massage and music therapies attenuate frontal EEG asymmetry in depressed adolescents. *Adolescence*, 34, 534–539.
- Joule, R. V., & Gueguen, N. (2003). Touch, compliance, and awareness of tactile contact. *Perceptual and Motor Skills*, 104, 581–588.
- Jourard, S. M. (1996). An exploratory study of body-accessibility. *British Journal of Social and Clinical Psychology*, 5, 221–231.
- Kandel, E., Schwartz, J. H., & Jessell, T. M. (2000). *Principles of neural science* (4th ed.). New York: McGraw-Hill.
- Kim, M. S., Cho, K. S., Woo, H., & Kim, J. H. (2001). Effects of hand massage on anxiety in cataract surgery using local anesthesia. *Journal of Cataract and Refractive Surgery*, 27, 884–890.
- Kubsch, S. M., Neveau, T., & Vandertie, K. (2000). Effect of cutaneous stimulation on pain reduction in emergency department patients. *Complementary Therapies in Nursing and Midwifery*, 6, 25–32.
- Kutner, J. S., Smith, M. C., Corbin, L., Hemphill, L., Benton, K., Mellis, B. K., et al (2008). Massage therapy versus simple touch to improve pain and mood in patients with advanced cancer: A randomized trial. *Annals of Internal Medicine*, 149, 138.
- Lagercrantz, H., & Changeux, J. P. (2009). The emergence of human consciousness: From fetal to neonatal life. *Pediatric Research*, 65, 255–260.
- Lahat, S., Mimouni, F. B., Ashbel, G., & Dollberg, S. (2007). Energy expenditure in growing preterm infants receiving massage therapy. *Journal of the American College of Nutrition*, 26, 356–359.
- Lee, H. K. (2006). The effects of infant massage on weight, height, and mother–infant interaction. *Taehan Kanho Hakhoe Chi*, 36, 1331–1339.
- Light, K., Grewen, K., & Amico, J. (2005). More frequent partner hugs and higher oxytocin levels are linked to lower blood pressure and heart rate premenopausal woman. *Biological Psychology*, 69, 5–21.
- MacLean, K. (2003). The impact of institutionalization on child development. *Development and Psychopathology*, 15, 853–884.
- McCabe, C., Rolls, E. T., Bilderbeck, A., & McGlone, F. (2008). Cognitive influences on the affective representation of touch and the sight of touch in the human brain. *Social Cognitive and Affective Neuroscience*, 3, 97–108.
- McGlone, F., Vallbo, A. B., Olausson, H., Loken, L., & Wessberg, J. (2007). Discriminative touch and emotional touch. *Canadian Journal of Experimental Psychology*, 61, 173–183.
- Meltzoff, A. N., & Borton, R. W. (1979). Intermodal matching by human neonates. *Nature*, 282, 403–404.
- Mendes, E. W., & Prociandy, R. S. (2008). Massage therapy reduces hospital stay and occurrence of late-onset sepsis in very preterm neonates. *Journal of Perinatology*, 28, 815–820.
- Mitchinson, A. R., Kim, H. M., Rosenberg, J. M., Geisser, M., Kirsh, M., Cikrit, D., et al (2007). Acute postoperative pain management using massage as an adjuvant therapy: A randomized trial. *Archives of Surgery*, 142, 1158–1167.
- Montagu, A. (1971). *Touching: The human significance of the skin*. New York: Columbia University Press.

- Montoya, P., & Sitges, C. (2006). Affective modulation of somatosensory-evoked potentials elicited by tactile stimulation. *Brian Research*, 1068, 205–212.
- Moszkowski, R. J., Stack, D. M., Girouard, N., Field, T., Hernandez-Reif, M., & Diego, M. (2009). Touching behaviors of infants of depressed mothers during normal and perturbed interactions. *Infant Behavior and Development*, 32, 183–194.
- Motamedi, N. (2007). *Keep in touch: A tactile-vision intimate interface*. British Columbia: Simon Fraser University.
- Mulleter, F., Vetere, F., Gibbs, M. R., Kjeldskov, J., Pedell, S., & Howard, S. (2005). Hug over a distance. *Extended abstracts CHI 2005*, 1673–1676.
- Nelson, C. A. (2007). A neurobiological perspective on early human deprivation. *Child Development Perspectives*, 1, 13–18.
- Neu, M., Laudenslager, M. L., & Robinson, J. (2009). Coregulation in salivary cortisol during maternal holding of premature infants. *Biological Research for Nursing*, 10, 226–240.
- O'Higgins, M., St James Roberts, I., & Glover, V. (2008). Postnatal depression and mother and infant outcomes after infant massage. *Journal of Affective Disorders*, 109, 189–192.
- O'Keane, V., Dinan, T. G., Scott, L., & Corcoran, C. (2005). Changes in hypothalamic-pituitary-adrenal axis measures after vagus nerve stimulation therapy in chronic depression. *Biological Psychiatry*, 58, 963–968.
- Ouchi, Y., Kanno, T., Okada, H., Yoshikawa, E., Shinke, T., Nagasawa, S., et al (2006). Changes in cerebral blood flow under the prone condition with and without massage. *Neuroscience Letters*, 407, 131–135.
- Ozdamar, O., Lopez, C. N., Oller, D. K., Eilers, R. E., Miskiel, E., & Lynch, M. P. (1992). FFT-based digital tactiler vocader system for real-time use. *Medical and Biological Engineering and Computing*, 30, 213–218.
- Pauk, J., Kuhn, C., Field, T., & Schanberg, S. (1986). Positive effects of tactile versus kinesthetic or vestibular stimulation on neuroendocrine and ODC activity in maternally-deprived rat pups. *Life Sciences*, 39, 2081–2087.
- Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *Psychoneuroendocrinology*, 23, 837–861.
- Post-White, J., Fitzgerald, M., Savik, K., Hooke, M. C., Hannahan, A. B., & Sencer, S. F. (2009). Massage therapy for children with cancer. *Journal of Pediatric Oncology Nursing*, 26, 16–28.
- Ramachandran, V. S., & Brang, D. (2008). Tactile-emotion synesthesia. *Neurocase*, 14, 390–399.
- Rolls, E. T. (2008). The affective and cognitive processing of touch, oral texture, and temperature in the brain. *Neuroscience and Biobehavioral Reviews*, 34, 237–245.
- Rolls, E. T., O'Doherty, J., Kringelbach, M. L., Francis, S., Bowtell, R., & McGlone, F. (2003). Representations of pleasant and painful touch in the human orbitofrontal and cingulate cortices. *Cerebral Cortex*, 13, 308–317.
- Russell, N. C., Sumler, S. S., Beinhorn, C. M., & Frenkel, M. A. (2008). Role of massage therapy in cancer care. *Journal of Alternative and Complementary Medicine*, 14, 209–214.
- Sann, C., & Streri, A. (2008). The limit of newborn's grasping to detect texture in a cross-modal transfer task. *Infant Behavior and Development*, 31, 523–531.
- Schanberg, S., & Field, T. (1987). Sensory deprivation stress and supplemental stimulation in the rat pup and preterm human neonate. *Child Development*, 58, 1431–1447.
- Shermer, M. (2004). A bounty of science. *Scientific American*, 290, 33.
- Spangler, G. (1997). Psychological and physiological responses during an exam and their relation to personality characteristics. *Psychoneuroendocrinology*, 22, 423–441.
- Suomi, S. J. 1984. The role of touch in rhesus monkey social development. In C. C. Brown, K. Barnard, & T. B. Brazelton (Eds.), *The many facets of touch. Johnson & Johnson pediatric round table #10* (pp. 41–50).
- Suresh, S., Wang, S., Porfyrus, S., Kamasinski-Sol, R., & Steninhorn, D. M. (2008). Massage therapy in outpatient pediatric chronic pain patients: Do they facilitate significant reductions in levels of distress, pain, tension, discomfort, and mood alterations? *Paediatric Anaesthesia*, 18, 884–887.
- Thayer, J. F., & Sternberg, E. (2006). Beyond heart rate variability: Vagal regulation of allostatic systems. *Annals of the New York Academy of Sciences*, 1088, 361–372.
- Vaidis, D. C., & Halimi-Falkowicz, S. G. (2008). Increasing compliance with request: Two touches are more effective than one. *Psychological Reports*, 103, 88–92.
- Weiss, W. J., Wilson, P. W., & Morrison, D. (2004). Maternal tactile stimulation and the neurodevelopment of low birth weight infants. *Infancy*, 5, 85–107.
- Wessberg, J., Olausson, H., Fernstrom, K. W., & Vallbo, A. B. (2003). Receptive field properties of unmyelinated tactile afferents in the human skin. *Journal of Neurophysiology*, 89, 1567–1575.
- Whitcher, S. J., & Fisher, J. D. (1979). Multidimensional reaction to therapeutic touch in a hospital setting. *Journal of Personality and Social Psychology*, 37, 87–96.