Paper

Human Development 2002;45:70–94

Human Development

Touch: Its Communicative Functions in Infancy

Matthew J. Hertenstein

University of California, Berkeley, Calif., USA

Key Words

Emotion communication · Emotional responses · Mother child communication · Physical contact · Tactile communication · Tactile perception · Tactile stimulation

Abstract

The communicative functions that the tactile modality serves in infancy have been severely neglected by researchers. The present article highlights the importance of touch by addressing two questions. First, *what* is communicated to infants by touch from their caregivers? In addition to the common notion that touch regulates arousal levels, it is argued that touch is capable of communicating valenced and discrete emotions as well as specific information. Second, *how* does meaning come about from the touch that adults administer to infants? This question is addressed by discussing specific qualities and parameters of touch and three mechanisms by which infants gain meaning from touch. Empirical evidence is provided and hypotheses are made regarding each of these questions. Furthermore, a preliminary model of tactile communication is presented based upon the literature on touch, as well as the conceptual framework outlined in the article.

Touch has been described as the most fundamental means of contact with the world [Barnett, 1972], and the simplest and most straightforward of all sensory systems [Geldard, 1960]. Many researchers have implicated the importance of touch in several domains of the infant's life, including social, cognitive, and physical development [e.g., Field, 1988; Greenough, 1990; Hertenstein & Campos, in press; Stack, in press]. However, one crucial, but relatively neglected, area of study involves the communicative functions of touch; researchers have focused almost exclusively on the face and the

KARGER

Fax + 41 61 306 12 34
E-Mail karger@karger.ch
www.karger.com

Accessible online at:
www.karger.com/journals/hde

Matthew J. Hertenstein
University of California, Berkeley, 3210 Tolman Hall
Berkeley, CA 94720-1650 (USA)
E-Mail mat@socrates.berkeley.edu

voice in infant communication. In the present article, I discuss the communicative functions that the tactile modality serves as it relates to how adults touch infants.

Two fundamental questions are addressed. First, *what* is communicated to infants by touch from their caregivers? In addition to the common notion that touch regulates arousal levels and behavioral state, I argue that touch is capable of communicating valenced and discrete emotions as well as specific information. Second, *how* does meaning come about from the touch that adults administer to infants? This question is addressed by discussing the physical dimensions of touch, as well as by discussing three mechanisms by which meaning from touch comes about. Finally, I propose a model of caregiver-infant tactile communication and suggest future directions for research. The article is meant to be a heuristic enterprise, rather than a definitive answer to the issues and challenges presented herein.

Although the present article primarily focuses on touch that is administered by adults to infants, it is readily apparent that infants use touch to communicate to their caregivers as well. Nevertheless, I do not address the latter phenomenon as it is beyond the scope of this article.[1] Furthermore, I do not discuss the infant massage literature as this has been reviewed elsewhere [for a thorough review, see Field, 1998].

Definitional and Conceptual Issues

Because the present article focuses on two phenomena – touch and communication – and their relations, it is necessary to define and conceptualize these terms. The word 'touch' is semantically rich. In fact, the *Oxford English Dictionary* has dedicated hundreds of lines to define touch [Reite, 1990]. Unlike other forms of communication, separate terms regarding touch do not exist for the communication process (e.g., gaze, speech) or the sensory process (e.g., vision, hearing) [Major, 1981].

Touch can refer to two highly dissociable phenomena:[2] (a) the action of an object on the skin and (b) the registration of information by the sensory systems of the skin (what in common usage we call feeling). The dynamics of tactile stimulation upon the infant's skin and the temperature of the caregiver's skin would thus be aspects of the former sense of the word, while the activity of nocioceptive nerves (i.e., pain receptors) or feeling ticklish would be aspects of the latter sense of the word (i.e., sensory registration).

The relations between touch and communication are very different depending on the global aspect of touch to which one refers. For instance, a person may attempt to tickle two infants using identical qualities of touch at the same location on the body (i.e., in the former definition of the word touch), yet only one infant perceives being tickled while the other is indifferent to the stimulation (i.e., in the latter definition of the word touch). In other words, the tactile stimulus pattern that is administered to the infant and

[1] The interested reader should see Landau [1989] for one of the few studies that examines infants' use of social touch.

[2] Touch refers here to cutaneous processes primarily, but kinesthetic processes are involved as well because they are difficult to separate one from the other. Together, cutaneous and kinesthetic processes comprise the somaesthetic sense.

what the infant perceives are not isomorphic. To help clarify the difference between the two meanings, I use the words 'touch', 'tactile stimulus', 'tactile form,' and 'tactile pattern' in reference to the action of an object on the skin and 'feel' in reference to the sensory reception of touch.

When using the word 'communication' I do not mean to connote that infants consciously understand the contents of tactile communication. Instead, tactile communication occurs whenever there are systematic changes in another's perceptions, thoughts, feelings, and/or behavior as a function of another's touch in relation to the context in which it occurs. This definition, which derives from a functionalist conception of communication, encompasses both emotional and non-emotional communication, both of which will be discussed later [Barrett & Nelson-Goens, 1997].

The operational definition I provide is broad in scope and refers to two dissociable aspects of communication. First, touch may transmit the caregiver's perceptions, thoughts, and/or feelings to the infant. For example, the caregiver may be angry and the emotional state may be transmitted to the infant such that the infant perceives the caregiver's state (whether or not anger is generated in the infant or not is a separate issue and will be discussed below). In contrast, the second facet of communication does not require that the caregiver's perceptions, thoughts, and/or feelings be transmitted to the infant. Instead, the caregiver's touch may influence that infant's perceptions, thoughts, feelings, or behaviors without actually transmitting the caregiver's perceptions, thoughts, or feelings. The touch that the caregiver administers to the infants is communicative and regulates the infant's perceptions, thoughts, feelings, or behaviors. For example, the caregiver may elicit a negative emotion in the infant by abruptly touching the infant, but the caregiver may not necessarily be experiencing a negative emotion. In this case, a state is elicited in the infant, but the caregiver's perceptions, thoughts, or feelings are not transmitted to the infant.

In sum, the infants' perceptions, thoughts, feelings, and/or behavior are regulated as a function of caregivers' touch in both facets of communication. However, it is not necessary that caregivers transmit information about themselves for communication to occur. In the present article, I refer to both facets as 'communication', acknowledging that touch need not always transmit caregivers' perceptions, thought, or feelings for tactile communication to occur.

Three distinctions must be made regarding communication. First, caregivers may or may not be mindful that they are providing tactile stimulation to their infants for communication to occur. A mother who is thinking about her day at work may be on 'automatic pilot' while changing her infant's diaper such that she fails to pay attention to the touch she is administering to her infant. In contrast, another mother may be mindful of the diaper-changing episode and attend to how she is touching her infant. Communication via the tactile modality may occur in both cases even if the caregiver is not mindful that she is touching the infant.

A second distinction regarding communication involves the intentionality of the caregiver. There has been a longstanding debate about whether or not the intentionality of the caregiver should be a criterion for 'true' communication [Andersen, 1991; Bavelas, 1990; Hinde, 1997; Knapp, 1984; Motley, 1990a; Motley, 1990b; Motley, 1991; Watzlawick, Beavin, & Jackson, 1967]. Some hold that a given behavior must be intentionally displayed and be goal directed for 'true' communication [e.g., Watzlawick et al., 1967], whereas others believe that intention should not be a criterion for communication [e.g., Hinde, 1997]. The definition of tactile communication provided here aligns

with the position that the caregiver need not touch or communicate with the infant intentionally to constitute communication. A father administering harsh touch to his infant while replacing his infant's diaper may be communicating to the infant even though he does so unintentionally. Likewise, a mother holding her infant after an extraordinarily stressful day at work may be communicating her anxiousness to the infant, even though she has no intention of doing so.

A third distinction involves the link between the communication of the caregiver's emotional experience and the generation of emotion in the infant. The distinction is important because a caregiver's emotional experience may be transmitted to the infant, but the emotion may not be generated in the infant. An infant may perceive that his caregiver is fearful, but fear may not be generated in the infant per se ('My caregiver is fearful, but I am happy.'). The same holds true for information of a non-emotional nature. A caregiver may communication that he is fatigued, for example, but this does not necessarily generate fatigue in the infant. In short, a caregiver's state may not necessarily be generated in the infant for communication to occur.

Touch: A Neglected Modality of Communication

No one can doubt that touch is a major component in infant-caregiver interaction. The importance of touch is indicated, in part, by the amount of time that infants are touched by their caregivers. In one US sample, infants were touched for 33–61% of the time during brief interactions with their mothers [Stack & Muir, 1990], but this is much higher in some cultures including the !Kung, where mothers spend 75% of their time in contact with their infants [Konner, 1976]. Similar amounts for physical contact have been reported amongst the Efe tribe, a community of foragers residing in the Ituri Forest of Zaire [Tronick, 1995].

The apparent universality of touch in the infant-caregiver relationship leads to an interesting hypothesis. Lorenz [1943] postulated that infants' physical characteristics constituted what he called 'babyness' and that these characteristics encourage parents to care for their offspring. These characteristics include disproportionately large heads, a prominent forehead, large eyes, and round protruding cheeks. In line with Lorenz's hypothesis, it is probably no accident that infants' skin is smooth and satin-like. Because the skin is so soft, it may afford touch by caregivers compelling them to provide tactile stimulation. At present, there is no empirical evidence for this hypothesis, but it is interesting to ponder given the apparent universality of touch in the infant-caregiver dyad.

Over four decades ago, Frank [1957] commented that the study of touch and tactile communication was severely neglected. Frank's comment still rings true today. In fact, Walker-Andrews [1997] recently reviewed the literature on infants' perceptions of others' expressive behaviors and, while the breadth of the article was extensive, no studies were reviewed focusing on infants' perceptions of expressive behavior through touch. To date, the study of touch and its relation to communication has been neither systematic, nor broad; the lack of knowledge about tactile communication represents a sizeable lacuna in our knowledge about the caregiver-infant communication system. The embryonic stage of research on tactile communication stands in stark contrast to the field of haptic perception (i.e., the perception of objects using touch) where greater strides have been made [Bushnell & Baxt, 1999; Bushnell & Bourdreau, 1991; Rose & Ruff, 1987].

The dearth of literature on the role of touch in communication is surprising considering that touch may be an extraordinarily powerful sensory system for the communication of emotion and other information. Why have researchers not mined this potentially rich vein? Both methodological and historical factors seem to account for researchers' neglect of tactile communication. Perhaps the primary methodological reason is that it is very difficult to measure. Tactile patterns are extremely complex, containing many degrees of freedom in any given pattern of touch. As will be discussed, a particular touch can vary in its action (e.g., stroking, rubbing, squeezing), intensity, velocity, abruptness, temperature, location, frequency, duration, and extent of surface area touched. While the perceptual richness and complexity of touch is ideal for communicative purposes, it is difficult to measure some of the qualities and parameters of touch. For example, it is difficult to measure the exact intensity of a particular pattern of touch from videotaped interactions between mothers and their infants. Difficulties like this have proved to be challenging for researchers who have devised coding systems to measure tactile stimulation [Stack, LePage, Hains, & Muir, 2001, as cited in Stack, in press; Stepakoff, Beebe, & Jaffe, 2000; Weiss, 1992]. The methodological challenges faced by researchers studying touch stand in contrast to those studying the face and voice where the challenge of measurement has been addressed with relative success [e.g., Ekman, 1999; Izard, 1979; Oster, 2001; Scherer, 1986]. Clearly, further refinement of tactile measures is in order and would benefit the study of tactile communication significantly.

Historical developments in Western philosophy also account for the neglect of research on touch. Since the time of Plato, philosophy has been dominated by metaphors and examples that privilege vision over other modalities. Historically, the vast majority of philosophers believed that vision offered the clearest and most veridical perception of the world, both of which are of fundamental importance in philosophy. This belief, in part, resulted in the majority of philosophers and scientists relegating the other perceptual modalities and focusing the majority of their intellectual energies on the study of vision [for an exception, see Merleau-Ponty, 1962]. That many major universities have an entire department dedicated to the study of vision attests to the fact that the visual modality dominates researchers' attention.

What Does Touch Communicate to the Infant?

Though the study of touch has been limited, a substantial body of literature has accumulated indicating that touch soothes and arouses, as well as regulates the infant's state [Kisilevsky, Stack, & Muir, 1991; Montagu, 1986]. However, touch may also serve other communicative functions [e.g., Cannon, 1977; Frank, 1957; Peláez-Nogueras et al., 1997; Stack & Muir, 1992]. This idea is in line with functionalist theories that stress the principle of equipotentiality in communication [Barrett & Campos, 1987; Witherington, Campos, & Hertenstein , in press]. This principle refers to the idea that the same communicative outcome can be achieved via a number of different pathways. As mentioned at the outset of this article, researchers have focused on two particular pathways for communication – the auditory (i.e., the voice) and the visual (i.e., the face). If the principle of equipotentiality operates in communication, it is probable that the tactile modality communicates to the infant as well.

In this section, I postulate what might be communicated by touch – emotions and other information – and review research suggesting that touch serves a communicative

function. The scope of the research to be reviewed is limited to those studies in which touch is examined explicitly or a reasonable inference can be drawn regarding the role of touch as opposed to other means of communication.[3] Exceptions are noted.

Emotions

The word 'emotion' is derived from the Latin 'to move out', suggesting that one facet of emotions is bodily movement and action. This notion is in complete accord with contemporary emotion theory. Frijda [1986] holds that tendencies to act in relation to others are fundamental to the concept of emotion. In any given interaction, one can observe a mother emoting through touch to 'move out'. In addition to the mother's action tendencies, there is evidence to indicate that her physiology differs as a function of the particular emotion that she experiences [e.g., Levenson, 1992]. Her respiratory patterns, skin temperature, perspiration, and pulse may also be perceived by an infant held in close contact.

Touch may also provide information regarding the caregiver's action readiness. Action readiness refers to a person's preparation to act and implement a motor program to establish, maintain, or change a relationship to an event of significance to that person [Barrett & Campos, 1987; Frijda, 1986]. The caregiver's action readiness may, for instance, be specified by the contraction of particular muscle groups, as well as by expanding or deflating the lungs. Action readiness may be communicated to the infant by touch and thereby help the infant predict what the caregiver is going to do in the future.

Valenced Emotions. Touch may be an extraordinarily powerful sensory system for communicating hedonically valenced emotions. The skin contains receptors that directly generate hedonic values, either because there are portions of the skin that are erogenous or because there are nerve endings that are nociceptive. Because hedonic processes are one of the primitives in the generation of emotion [Campos, Mumme, Kermoian, & Campos, 1994], the skin senses must be considered central to the study of emotion. In the following sections, I review some of the literature suggesting that touch communicates positive and negative emotions.

Positive Emotion. A number of studies indicate that touch is capable of communicating and eliciting positive emotions. Wolff [1963] studied the development of smiling in the early life of the infant and reported that the widely known game of 'pat-a-cake' becomes an effective generator of positive emotions in infants as indicated by their intense and broad smiles. Wolff inferred that tactile stimulation, and not other stimulation, resulted in infant smiling because the infants played the game without being able to see or hear the interactive adult.

More recently, researchers have showed that touch adds to the positive reinforcement value of other forms of reinforcing stimulation [Peláez-Nogueras, Gewirtz, Field,

[3] The literature on bonding between mother and infant is not included because methodological difficulties in these studies make it troublesome to infer the unique contribution(s) of touch.

& Cigales, 1996b]. Peláez-Nogueras et al. [1996b] used a contingency-based technique (the synchronized reinforcement procedure) to measure infants' preferences for social stimulation. The investigators used this procedure to reinforce infant eye-contact to the experimenter with two reinforcers: a stimulus compilation that included the face, voice, and touch of an adult versus one that did not include touch. Infants between 1.5 and 3.5 months old who received touch emitted more smiles and vocalizations and spent less time crying than infants receiving no touch. In a subsequent study, Peláez-Nogueras et al. [1997] compared the reinforcement effects of tickling and poking to systematic stroking on 2- to 4.5-month-old infants when they made eye contact with the experimenter. The investigators reported that infants in the stroking condition smiled and vocalized more and cried less than infants in the tickle/poke condition. This line of research demonstrates that touch is capable of eliciting positive emotion.

Researchers have also shown that touch elicits infant smiling during a maternal still-face [Stack & Muir, 1990; Stack & Muir, 1992]. In the still-face paradigm, the adult assumes an expressionless and stationary facial display directed to the infant while remaining silent – a condition that results in considerable frustration and upset in some infants [Tronick, Als, Adamson, Wise, & Brazelton, 1978]. Stack and Muir [1990] found that when mothers were instructed to touch their 5-month-old infants during the still-face period (maternal contact being left free to vary), their infants displayed significantly less grimacing and more smiling compared to infants whose mothers had not touched them during this period. In a subsequent study, Stack and Muir [1992] ruled out the alternative possibility that the infants' emotional displays were mediated by seeing their mothers' hands move.[4] Interestingly, other researchers have demonstrated that infants of depressed mothers displayed more positive expressions than infants of nondepressed mothers receiving no touch in the still-face paradigm [Peláez-Nogueras, Field, Hossain, & Pickens, 1996a]. These findings, together with Stack and Muir's [1990, 1992], indicate that touch generates positive emotional displays, as well as modulates negative ones.[5]

Negative Emotion. It makes intuitive sense that touch communicates and elicits negative emotions in the infant. While not typically investigated experimentally (perhaps because of ethical reasons), several studies have indicated that touch is capable of eliciting negative emotion. Brossard and Decarie [1968] explored a number of stimuli varying in complexity that reinforce smiling in 16- to 20-week-old infants. While picking up the infants reinforced infants most effectively, laying a hand on the infants' abdomens for 30 s with little pressure (i.e., static touch) took the most amount of time to reinforce infant smiling. Furthermore, infants displayed the most amount of tension when they were touched statically. Brossard et al.'s [1968] results indicate that some types of touch, at least static touch, are aversive.

[4] Stack and Muir's [1990, 1992] studies demonstrate the important relation between touch and the infant's visual attention. Stack and Muir showed that if the mother's hands were visible while touching the infant, the infant would direct his/her smiling and attention to the hands [Stack & Muir, 1990], whereas if the hands were invisible, the infant would smile and attend to the mother's still-face. Furthermore, touch preempted the negative message communicated by the still-face.

[5] I have interpreted Stack and Muir's [1990, 1992] findings as indicating that positive emotions were generated in the infant. However, it is maybe that positive emotions were not generated, but instead, negative emotions were modulated. In either case, their results indicate that touch increased infant smiling.

Weiss and her colleagues demonstrated that some types of touch, especially harsh touch, experienced early in life were associated with later emotional and behavioral problems [Weiss, Wilson, Seed, & Paul, in press]. The researchers videotaped 3-month-old infants being fed by their mothers and coded the tapes for mother-infant interaction, including maternal touch. The infants' social adaptation and emotional/behavioral problems were indexed when the children were 2 years old. The results indicated that infants who had received harsher and more frequent touch demonstrated more aggressive and destructive behaviors while infants who had received more nurturing touch had significantly less depression and anxiety. These results suggest that touch not only affects infants' emotional lives in the short term, but also across a protracted period of time.

Recently, Hertenstein and Campos [in press] demonstrated that maternal touch can elicit negative emotional displays in 12-month-old infants and can regulate their instrumental behaviors toward objects in the world. Infants sat on their mothers' laps facing away from their mothers while novel objects were presented serially by the experimenter to the dyad. As each object was presented, the mothers administered tactile stimulation that was predicted to generate negative emotion in the infant by abruptly pressing their infants' abdomens with their fingers while inhaling suddenly. The infants touched the objects less and waited longer to touch the objects, while displaying more negative emotional expressions, compared to infants in a control condition. This study demonstrates that touch not only affects infants' emotional displays, but their instrumental behaviors toward objects as well.

Studies of depressed mothers also indicate that touch communicates negative emotions to infants. A number of studies have documented that depressed mothers tend to poke, tickle, and jab their infants during interaction more than nondepressed mothers [Cohn & Tronick, 1989; Field, Healy, Goldstein, & Guthertz, 1990; Stepakoff et al., 2000]. These behaviors have been associated with infants' negative emotional displays indicating again that caregivers can readily generate negative emotions via the tactile modality [Tronick, 1995].

Discrete Emotions. In addition to valenced (positive or negative) emotions, touch may also communicate specific emotions. One feature of the so-called 'basic' emotions is multimodal specification; that is, emotions like sadness, fear, anger, joy, surprise, and disgust can be communicated both by the face and the voice [Campos, Barrett, Lamb, Goldsmith, & Stenberg, 1983; Walker-Andrews, 1997]. In general, phenomena such as distance, direction, and speed that are multimodally specified in sight and sound are also specified by touch [Stern, 1985]. The infant likely uses these temporal and spatial cues to perceive emotion, even discrete emotions. For example, anger may be specified when the caregiver touches the infant with an abrupt grasp, a high degree of intensity, a high finger to palm ratio of contact, an abrupt release, and skin that feels relatively hot. While little empirical evidence exists to support the communication of specific emotions, there is some suggestive evidence [Clynes, 1977; Dickson, Walker, & Fogel, 1997; Stack & Arnold, 1998; Stack & LePage, 1996; Stack & Muir, 1990, 1992].

One relevant approach to the study of touch and discrete emotions is that of Clynes [1977] whose studies demonstrate that there is cross-cultural agreement among research participants in the dynamics that they use when expressing discrete emotions. Clynes used a pressure-sensitive keypad from which he plotted the vertical and horizontal components of transient fingertip pressure to identify the patterns for each of these emo-

tions. Using university students from the United States and a variety of other countries around the world, Clynes identified universal expressive patterns of touch whereby specific emotions were associated with particular tactile patterns and dynamics. For example, the graph of key pressing as a function of love had a shallow, sweeping curve, whereas key pressing as a function of anger dipped suddenly and rebounded to a height greater than the initial level. Although this line of research indicates that there is a universal pattern of expressing discrete emotions using *fingertip pressure* on a keypad, we do not know if the dynamics of fingertip pressure map onto *tactile patterns* that are used to communicate emotions.

In the developmental realm, studies indicate that infants are sensitive to subtle changes in tactile stimulation and that they respond appropriately to specific qualities of touch. Perhaps the best empirical support for this comes from the work of Stack and her colleagues [Stack & Arnold, 1998; Stack & LePage, 1996]. As reviewed earlier, Stack and Muir [1990, 1992] found that maternal touch generated positive emotional displays and/or mitigated negative ones in the still-face paradigm. Building on this work, Stack and her colleagues were curious to know if infants were sensitive to specific qualities of touch and whether mothers could effectively elicit specific responses from their infants.

Stack and her colleagues conducted a series of studies indicating that mothers are able to elicit specific responses from their infants via touch. Stack and LePage [1996] instructed mothers to interact with their 5.5-month-old infants in four periods (each separated by 20 s): (1) normal interaction (including the face, voice, and touch); (2) still-face while interacting with infants through touch (touch being free to vary); (3) still-face while touching infants so as to obtain the maximum amount of smiling, and (4) still-face while touching infants on only one area of the body. When mothers were instructed to obtain the maximum amount of smiling through touch, infants smiled equally as mush as in the normal interaction period and more than in the other two still-face periods.

Stack and Arnold [1998] conducted a similar within-subjects study in which they instructed mothers to assume a still-face in 3 periods of interaction with their 5.5-month-old infants, after a period of normal interaction. Mothers were instructed to (1) get their infants to imitate them using touch; (2) engage their infants in a playful interaction using touch, and (3) attract and maintain their infants' attention on their faces with as much eye-to-eye contact as possible using touch. The results indicated that when mothers were instructed to engage their infants in a playful interaction using touch, infants smiled more than in the normal interaction period. Furthermore, mothers successfully attracted infants' attention to their face using touch, even with a still face. These results, in concert with those of Stack and LePage [1996], indicate that infants are sensitive to the specific qualities of touch rather than its mere presence or absence. Moreover, the results also suggest that mothers are capable of eliciting specific behaviors from their infants using touch.

A different line of work also suggests that touch elicits specific infant behavioral responses. Dickson, Walker, and Fogel [1997] examined the relation between morphologically distinct types of smiles – basic, play, and Duchenne[6] – and the social context in

[6] Each of these smiles was coded using Baby FACS [Oster, 2001] which specifies the specific muscle groups that contract. A basic smile is characterized by lip corner raises caused by a contraction of the zygomatic muscle; a play smile is coded when the jaw drops open and the lip corners are raised; a Duchenne smile is coded when the orbicularis oculi contracts and raises the cheeks, in addition to lip corner raises [Dickson, Fogel, & Messinger, 1998].

which these smiles are elicited (i.e., parent-infant interactions consisting of object play, physical play, vocal play, and book reading). It is believed that each of these smiles is context specific. Dickson et al. [1997] found that physical play that included tactile stimulation elicited play smiles 45% of the time compared to 28 and 27% for basic and Duchenne smiles, respectively. Moreover, play smiles only occurred 30, 18 and 6% of the time during object play, vocal play, and book reading, respectively. The following observation of a father with his infant during physical play: 'Her vocalizations fluctuate at the same speed in which he is tickling her stomach with his face and fingers in a side to side fashion' [p. 930] suggests that specific qualities of touch may result in specific infant responses (although confounded with other modalities).

Overall, evidence indicates that infants are sensitive to very specific qualities and parameters of touch. The evidence indicates that it may be possible for infants to be responsive to the communication of discrete emotions. However, much more empirical evidence is needed to support this hypothesis.

Specific Information. In addition to emotional content, tactile communication may transmit specific information to the infant [Tronick, 1995]. Touch may communicate, for example, the presence or absence of a caregiver or the identity of the person who touches the infant. Most often, the information communicated through touch will be of emotional significance to the infant such that a concomitant emotion will be communicated and elicited in the infant. However, specific messages need not necessarily communicate or elicit emotion.

Tronick [1995] reported two studies as evidence suggesting that touch communicates specific messages. The first study indicated that qualitatively different types of touch (i.e., maternal stroking, rhythmic touching, holding, tickling, kissing, and poking/pinching) are used by mothers during face-to-face interactions with their 6-month-old infants. Stroking, rhythmic touching, and holding the infant occurred most often, followed in frequency by tickling and kissing; poking and pinching occurred the least.

The second study investigated the independent roles of touch, vision, and voice in mother-infant interaction [Brown & Tronick, unpubl., as cited in Tronick, 1995]. There were five conditions in this study; the infant either: (1) participated in a normal play session in which the mother talked, touched and vocalized; (2) could only see the mother; (3) could only hear the mother; (4) could only feel the mother's touch, or (5) was left alone. Infants who were touched only, compared to the normal play and face-only conditions, responded in an affectively and behaviorally subdued manner, exhibited low levels of fussing or crying, were less stressed (as indexed by a low level of scanning), attended to objects more, and smiled less. On the basis of these data, as well as other studies of touch [e.g., Stack & Muir, 1990; Stack & Muir, 1992], Tronick [1995] suggested that a specific type of touch can convey 'very specific messages to the infant and that these messages are just as specific as the messages conveyed by other forms of affective displays, such as facial expressions' [p. 64].

The field of attachment does, however, shed light on one message communicated through touch and contact: security. Attachment theorists have long regarded the quality of parent-infant physical touch as a central feature of the responsive and available caregiving environment that is necessary to foster an infant's sense of security [Ainsworth, Blehar, Waters, & Wall, 1978; Bowlby, 1973]. Main [1990] has argued that physical contact with an attachment figure is 'the ultimate signal' to the infant that he is safe and secure, noting that Bowlby [1969] considered physical contact as a central require-

ment of proximity. In sum, some types of touch signal to the infant that he or she is in a 'haven of safety' and therefore secure and safe from endangerments in the environment.

Many attachment theorists hold that the infant develops an internal working model in which the infant comes to represent the interactional history of the caregiver-infant dyad [Bretherton, Biringen, Ridgeway, & Maslin, 1989; Main, Kaplan, & Cassidy, 1985; Sroufe, 1996]. Researchers from this tradition believe that an internal working model in which the caregiver is represented as available (especially in stressful circumstances) leads to a secure attachment relationship, whereas an internal working model in which the caregiver is represented as unavailable or inconsistently responsive results in an insecure attachment relationship. Touch undoubtedly plays a crucial role to signal the availability of the caregiver. If the infant is distressed and the caregiver is available (and 'sensitive'), she will often provide the infant with touch, thereby attenuating the infant's distress. However, the less sensitive caregiver is more likely to be reluctant to touch the infant or do so awkwardly, and thus not convey security [Ainsworth et al., 1978].

There is some evidence to indicate that there are deleterious effects when caregivers reject physical contact, especially ventral-ventral contact, with their infants. As mentioned, touch is the ultimate signal that the caregiver is present and that the infant is safe and secure in stressful situations [Main, 1990]. However, some parents do not provide this security through touch to meet infants' needs for security. In one sample of infants followed over the first year of life, Main and Stadtman [1981] found a significant relation between mother's aversion to physical contact with the infant in the first quarter of life, and displays of infant aggressiveness and anger (e.g., hitting the mother) in the last quarter of the first year. Moreover, the researchers found a robust relation between maternal aversion to contact with the infant in the early months of life and displays of odd behavior by the infant (e.g., stereotypies, echoing speech, hand-flapping, and hair-pulling) later in the first year.[7]

One experimental study suggests that contact does, in fact, provide security and thereby leads to a secure attachment relationship [Anisfeld, Casper, Nozyce, & Cunningham, 1990]. In one of the few studies manipulating the amount of physical contact between mothers and their infants, the investigators compared attachment outcomes for infants who were carried ventrally in soft infant carriers with those transported in infant seats. Anisfeld et al. found that infants carried in soft infant carriers were more likely to be judged secure than those carried in infant seats. The results suggest that security may be communicated through touch. However, it is possible that mothers were more responsive to their infants' emotional signals when in the soft infant carriers thereby mediating the effect of contact.

Recently, Weiss, Wilson, Hertenstein, and Campos [2000] investigated the relation between maternal touch and infants' attachment classification. Three-month-old infants and their mothers were videotaped during a feeding session in which maternal touch, maternal sensitivity, and infant responsiveness were coded. Infants' attachment

[7] These odd behaviors are characteristic of infants classified as 'disorganized/disoriented' in the Ainsworth Strange Situation [Main, pers. commun., April 11, 2001].

classifications were indexed at 12 months of age. There was no relation between the sheer frequency and duration of touch that mothers administered to their infants and infants' attachment classifications 9 months later. Nonetheless, infants who received nurturing touch at 3 months were more likely to be classified as 'secure' when they were 12 months old, compared to infants who received less nurturing touch. However, the degree of infant vulnerability (i.e., perinatal complications, birth weight, and responsiveness) moderated the effects of nurturing touch; nurturing touch was associated with more secure attachment for robust infants but with less secure attachment for highly vulnerable infants. Neither maternal sensitivity nor gender moderated the relation of touch to attachment or had any direct relation to attachment outcomes. These findings emphasize the importance of the quality of touch (in this case, nurturing touch for robust infants) rather than the sheer frequency of touch for infants' socio-emotional development.

Overall, the studies suggest that touch serves a variety of communicative functions in infancy, including the communication of valenced emotion, discrete emotions, and specific information. However, more research is needed to fully delineate these and other communicative functions that touch serves.

Physical Dimensions of Touch

Although it is evident that touch is communicative, we must begin to understand how the contents of tactile communication are transmitted to the infant. Thus, we must consider the properties of touch used by the caregiver to communicate and the potential mechanisms that the infant uses to 'interpret' them. Furthermore, it is imperative to consider how touch interacts with the contexts in which infants find themselves.

It is readily apparent that infants are exposed to many types of touch every day. For example, the caregiver may caress, stroke, kiss, embrace, nuzzle, pat, tap, graze, fondle, squeeze, pinch, poke, jab, and scratch the infant, to name only a few forms of touch. The forms of touch that are administered to a given infant at a given time all depend on the context of the situation, as well as the particular caregiver. All forms of touch can be conceptualized within a number of specific dimensions. A few researchers have provided analytic frameworks to describe touch [e.g., Geldard, 1960; Weiss & Campos, 1999]. For example, Geldard differentiated between qualities of touch that are mechanical (i.e., locus, intensity, duration, and frequency) and non-mechanical (i.e., thermal, chemical, and electrical). Weiss et al. [1999] have provided a conceptual framework in which she considers four 'qualitative symbols' of touch: duration, location, action, and intensity. In the present section, I build upon these frameworks and extend them so we might begin to understand how specific forms of touch communicate to the infant.

Most researchers examining the communicative functions of touch have focused on the sheer *quantity* of touch rather than the specific qualities and parameters of touch that play a role in communication. As Weiss [1990] points out, however, 'The meaning of a tactile experience cannot be derived solely from the mere presence or absence of touching' [p. 429]. Rather 'The *quality* of the cutaneous stimulation influences the meaning of the tactile message' [p. 430].

The studies reviewed earlier in which mothers administered touch to infants while concurrently presenting a still-face illustrates the importance of the quality of touch [Stack & Muir, 1990; Stack & Muir, 1992]. Stack and Muir [1992] found that static

touch during the still-face resulted in infant behaviors comparable to those evident during a standard still-face paradigm with no touch (i.e., displays of distress). In other words, compared to active forms of touch, passive touch resulted in negative infant emotional displays. While tactile communication is more complex than the passive vs. active touch dichotomy, this study provides evidence that it is not merely the presence or absence of touch that is important for tactile communication, but the quality of touch.

When considering touch as a mode of communication, one must consider both the qualities and parameters of touch because each relates to a different facet of communication. The *qualities* of touch (both active and passive modes of touch) refer to features of the actual tactile stimulus that is administered to the infant, whereas the *parameters* of touch (i.e., location, duration, frequency, and extent of touch) describe where and how much touch is administered. Although various qualities and parameters of contact are listed below serially, communication occurs when all of the components are orchestrated together, thereby resulting in a 'tactile gestalt'. Within the gestalt, many of the specific qualities and parameters of touch interact with each other. For example, the degree of intensity of the caregiver's touch will have very different consequences depending on the location of the touch; if the caregiver impresses upon the infant's skin two centimeters on the stomach, this may result in the infant smiling, whereas the same touch to the face would be aversive. In sum, the various qualities and parameters of touch interact and are integrated with one another.

Qualities of Touch

Action. The action of touch refers to the specific movements that one uses, such as stroking, rubbing, holding, or squeezing. As Weiss et al. [1999] point out, these movements provide three types of stimuli to the brain: *cutaneous* (stimulation of the surface receptors of the skin), *proprioceptive* (stimulation of end-organs in muscles, tendons, and joints), and *vestibular* (stimulation of semicircular canals due to spatial displacements). Of course, different tactile actions can have different effects on infants (e.g., poking an infant will have different regulatory effects than stroking).

Intensity. This intensity of touch refers to the degree of pressure that one uses to indent the skin of the other. The intensity can range from very light (the touch may even be subthreshold to the infant) to very intense pressure. Varying intensities will result in different degrees of nervous system activation. Thus, the regulatory effects of touch can vary widely depending on the intensity of the touch.

Velocity. This quality refers to the rate at which the caregiver impresses upon or moves across the infant's skin. The proper metric value can be characterized by dividing the 'distance' of the touch by the time that it takes to travel that distance (i.e., millimeters/milliseconds). The reverse situation can also be considered in which one examines the rate at which the caregiver removes his body from the infant's.

Abruptness. The abruptness of touch is similar to the velocity of touch, but it refers to the acceleration or deceleration that one uses to touch the infant. The proper metric value can be characterized by diving the 'distance' of the touch by the square of the time

it takes to travel the distance (i.e., mm/ms^2). As mentioned, Hertenstein and Campos [in press] found that a maternal tactile gestalt including abrupt touch to infants' abdomens regulated their emotional displays (more frowns than the control group) and instrumental behaviors toward objects (longer latency and less contact compared to the control group).

Temperature. The temperature of the caregiver's skin also relates to the quality of touch. Due to the intrinsically relational nature of touch, temperature perception is very dependent upon both the caregiver's and the infant's skin temperature. Studies of the human autonomic nervous system [e.g., Levenson, 1992] indicate that a person's finger temperature varies for some discrete emotions (e.g., fear and anger) which may contribute, in part, to specific emotions and messages being communicated to the infant. Thus, a caregiver's cold hands may specify fear to the infant, whereas very warm hands may specify anger.[8]

Parameters of Touch

Location. This parameter of touch refers to where the caregiver touches the infant's body. The meaning of some types of touch varies depending on the specific location at which the infant receives the touch. Thus, an infant may perceive touch differently when a caregiver caresses him on the forehead compared to the bottom of the feet. In addition to the differences in meaning, the degree to which the infant's skin is enervated by receptors and is represented in the somatosensory cortex depends on location. This, in part, dictates how well the infant is able to discriminate and localize different types of touch. Compared to the lower back, for example, the infant is very sensitive around the mouth and cheek areas and has very fine spatial discrimination of tactile stimuli around these locations.

Frequency. This parameter of touch refers to the number of times that the infant is touched by the caregiver. According to this definition, for example, a tap on the arm would be considered a frequency of one.

Duration. This parameter of touch refers to the time that elapses between initial contact and contact cessation. Following this definition, either person in the dyad may initiate contact and either person may terminate it. The duration of touch as it relates to tactile communication is of import because the longer the period that infants are touched, the longer they have to integrate the tactile information. Furthermore, repetitive touch may result in sensory adaptation or habituation, making it difficult for the infant to recognize that he or she is being touched [Weiss & Campos, 1999].

[8] It is unlikely, however, that only one quality or parameter of touch will specify a specific emotion, especially out of context.

Extent of Surface Area Touched. This parameter of touch refers to the surface area that is covered when the caregiver touches the infant. Thus, the amount of surface area touched during both a specific instance of touch and when specific instances of touch are aggregated across a series of touches are included within this parameter.

As I have indicated, touch has several dimensions that make it a very complex stimulus. Compounding this complexity is the fact that tactile communication is intrinsically relational [Stack, in press]. Simply stated, one cannot touch the other without being touched [Merleau-Ponty, 1962]. The perception of temperature is an excellent example that illustrates the relational quality of touch. An infant's temperature varies as a function of the time of day, as well as the level of arousal and emotion that the infant experiences. When an infant's body temperature is warm, it is more likely that the caregiver's touch will be perceived as cool, whereas when an infant is cool, touch is more likely to be perceived as warm. Thus, depending on the time of day and the infant's emotional state, touch of the same temperature will be experienced differently. Researchers should consider the relational nature of tactile communication when investigating the physical dimensions of touch.

How Does Touch Become Meaningful to the Infant?

I have discussed what might be communicated by touch, as well as the physical dimensions of touch that enter into tactile communication. However, the following question still remains unaddressed: *How* does the caregiver's tactile stimulation become meaningful to the infant? At one level of analysis, meaning derives from the way in which touch affects the nervous system and the cultural and personal meaning attributed to specific qualities and parameters of touch [Weiss & Campos, 1999]. However, at a different level of analysis, we still do not understand how the infant interprets the tactile gestalt. Three explanations are discussed in this section which may point the way to how infants acquire meaning from touch: direct perception, learning, and cognitive processes. Here I focus on touch that is given meaning by the infant (or, meaning that is picked-up in the tactile stimulus), in contrast to touch that directly communicates meaning due to pure sensory stimulation (e.g., the triggering of nocioceptive nerve endings or the touching of erogenous zones).

Direct Perception

The theory of perception put forth by James and Eleanor Gibson holds that organisms directly perceive meaning from stimulus arrays and that we do not need higher cognitive processes or previous experiences to construct meaning [Gibson, 1969, 1979]. Some have suggested that infants perceive the meaning of facial displays in this fashion [Buck, 1988; Campos et al., 1983; Stern, 1985; Walker-Andrews, 1997]; it is plausible that infants directly perceive the meaning of tactile stimulus arrays as well. In fact, Gibson [1966] postulated that the tactile system provides an adequate means of social interaction and communication independent of other perceptual systems.

From a Gibsonian perspective, stimulation (in this case, tactile stimulation) is a rich and structured source of information that extends over space and time and contains higher-order invariants. These invariants are present at a higher level of abstraction

than mere sensory stimulation and refer to the spatiotemporal relations present within the stimulus (e.g., the abruptness and velocity of a tactile stimulus). These higher-order invariants are detected by the organism and provide meaning about the stimulus array. From this perspective, touch is not static, nor is it frozen in time. It is inherently meaningful and the task for the infant is to detect and 'pick-up' higher-order invariants in the stimulus array.

A fundamental postulate of Gibsonian theory is that higher-order invariants are specified multimodally. That is, the same-order invariants present in the auditory and visual modalities are also present in the tactile modality. In line with Gibsonian theory, Walker-Andrews [1997] argues that infants recognize social signals by abstracting the meaning that is invariant across multiple modalities and that higher-order invariants are capable of specifying unique communicative affordances. 'The critical information specifying an emotion is found in the overall dynamic flow, particularly in the invariant patterns of movement and change undergone by facial musculature, body and voice' [p. 450]. There are some data to indicate that infants do, in fact, pick-up on these invariant patterns in the face and voice [for review, see Walker-Andrews, 1997]. It is likely that infants also pick up on higher-order invariants via the tactile modality specifying unique communicative affordances, although there are no available data that speak to this assertion. Thus, the role that direct perception plays in tactile communication awaits empirical investigation.

Gibsonian theory has two primary developmental implications for tactile communication [Gibson, 1969]. First, the correspondence between the information in stimulation and what is actually perceived by the infant increases in specificity with development. In other words, perception becomes more exact and differentiated. For instance, the neophyte wine taster may not distinguish between two different samples of white wine, while the wine connoisseur can do so effortlessly. Likewise, the newborn who lacks social tactile experience will not perceive meaning as finely as the older infant who has a longer history of tactile stimulation. The second implication of Gibsonian theory is that there will be increasing economy of information pick-up with development. The tactile system is the earliest to develop in the human embryo and is well developed by birth [Maurer & Maurer, 1988; Montagu, 1986]. Thus, while the mechanisms for detecting and extracting information are present from birth (at least in an immature form), they become more efficient over time. The net result of this is that with development, infants pick up distinctive features and extract invariants within the stimulus resulting in the communication of information through touch.

Learning

Touch may become meaningful to the infant through learning as well. Unlike Gibsonian theory in which the infant detects the information in the stimulus, a learning explanation holds that the infant makes associations between touch and environmental events to impute meaning on tactile patterns. Three types of learning may play a role in helping infants attribute meaning to various tactile forms: classical conditioning, operant conditioning, and observational learning.

Touch may become meaningful to the infant through respondent, or classical, conditioning [Frank, 1957]. With repeated pairings between a learned stimulus (e.g., a tactile stimulus) and an unlearned stimulus (i.e., any event that directly elicits a response),

the former acquires the capacity to elicit the same behavior as does the former. For example, a caregiver may scowl (an unconditioned stimulus) at his infant, thereby resulting in the infant retracting (an unconditioned response) from the caregiver. Just before scowling, the caregiver may characteristically grasp his infant's arm abruptly with a tight grip (a conditioned stimulus). With repeated parings between the caregiver's touch and scowl, the infant eventually retracts (a conditioned response) from the caregiver following the tactile gestalt presented by itself. With this learning mechanism, touch acts as a surrogate for other stimuli that inherently contain meaning for the infant [Frank, 1957].

Operant conditioning may also lead infants to attribute meaning to touch. Specific tactile forms may operate as discriminative stimuli that may lead infants to impute meaning on touch. The consequences that follow operant behavior provide the control that discriminative stimuli have on the infant's behavior. For example, an infant may stumble and fall to the ground and a caregiver may approach and pat the infant on the back. When the infant smiles in the presence of this particular tactile stimulus, he or she operates on the environment (in this case, on the caregiver) to produce encouraging behavior from the caregiver and, perhaps, continued succor. Thus, operant behavior (the infant's smile) is followed by a positive reinforcer (the encouragement and succor offered by the caregiver) in the presence of a discriminative stimulus (the pat on the back). After a number of learning experiences, the pat on the back may operate as a discriminative stimulus thereby increasing the probability that the infant will smile in the presence of the particular tactile stimulus in the future. Thus, the infant may derive meaning from the pat on the back (in this particular context) because of its association with other environmental events.

Observational learning may also account for the meaning that particular forms of touch have for infants [Bandura, 1965]. That is, infants may learn the meaning of specific types of touch by observing how others are touched and how they behave in relation to the touch they receive. Thus, if an infant observes that people are touched in a specific manner (e.g., caress) across a variety of contexts, but they react similarly, the infant may infer that the observed type of touch communicates something specific (e.g., love).

Cognitive Processes

Cognitive processes may also account for the meaning that some types of touch have for infants. At the very least, four processes that traditionally fall under the rubric of cognition may influence how infants impute meaning on touch: discrepancy, memory, appreciation of contextual cues, and attention.

Discrepancy processes may play an important role in helping infants impute meaning on touch. According to discrepancy theory, stimuli that moderately diverge from an infant's past experience, that require some degree of effort to incorporate into memory ('effortful assimilation'), but that nonetheless ultimately comply with memory, result in positive emotion [Kagan, 1971; Piaget, 1952]. Events that actively conflict with infant memory – familiar in some respects but discrepant enough to prove incompatible with past experience – produce negative emotion [Hebb, 1946].

Infants may habituate to qualitatively similar touch that is administered to them repetitively. If the principle of discrepancy is operating, infants will experience positive

emotion if the caregiver administers of form of touch that is slightly discrepant from the earlier form of touch (presumably, a reflection that infants are able to assimilate the new stimulus into an existent schema). However, if the caregiver administers touch that is actively in conflict with the infant's internal schema, negative emotion will result. Discrepancy processes, however, are insufficient for explaining either the generation of specific emotions or specific types of information [Witherington et al., in press]. Furthermore, the same event for the same infant can generate markedly different emotions depending on various contextual factors. Thus, discrepancy cannot account for all, or even most, meanings from touch.

Memory processes also influence how infants gain meaning from the touch that their caregivers administer. With memory, the infant draws upon prior tactile experiences (either consciously or unconsciously) to help make sense of tactile stimulation that they receive from others in the immediate context.

Memory processes not only play a role in remembering a given tactile pattern and its meaning, but the infant likely remembers the particular context in which the touch was administered. Memory for the particular context of tactile experiences likely influences the meaning of a given tactile stimulus. For example, an infant may encode and store in memory a particular meaning of a touch in the context of receiving the tactile stimulus from his or her grandfather. It may be that if the same form of touch is administered by the grandfather a week later, the infant will remember the meaning of the tactile stimulus. However, the infant may not remember the meaning of the same tactile form if it were administered by his or her mother. This example demonstrates how the infant's memory for contextual factors may influence the meaning that a particular pattern of touch has in a given situation.

In addition to memory, the infant's appreciation of the immediate context in which a tactile stimulus is administered likely influences the meaning of touch. The identical form of touch can have different meanings depending on the context in which it is administered. For example, an infant may attribute two different meanings to a light slap on the hand depending if the touch was administered in the context of a game compared to a context in which the child is being punished for a wrongdoing.

Attention may also influence the processes by which infants impute meaning on touch. Attention, as I use it here, refers to the process by which infants process limited amounts of information from the tremendous amounts of information available to them from the immediate environment. Traditionally, infants' selective attention has been indexed by the degree to which they gaze at one stimulus over another [e.g., Fantz, 1961]. For example, recall that Stack and Muir (1990) found that infants experiencing a still-face and touch visually attended to the their mothers' hands more than their mothers' faces [Stack & Muir, 1990]. In addition to the visual modality, infants likely selectively attend to stimuli in other modalities, including the tactile modality. Thus, when two different tactile patterns are administered concurrently (e.g., repetitive caressing on the back and repetitive stroking on the bottom of the foot), the infant may attend to one form of touch to the exclusion of the other. As a result of selective attention in the tactile modality, the meaning of different tactile forms is likely influenced, both in the immediate context and in future interactions.

It is probable that the mechanisms I have proposed do not account for the meaning of touch in all cases. For example, one need not rely on any of the three mechanisms I have discussed to account for the pain that an infant experiences because of a pinch received on the arm. The sensory qualities that touch engenders – in this case, the trig-

gering of nociceptive nerve endings – communicate information to the infant in very powerful ways. When one considers this in conjunction with the other potential mechanisms of meaning that I have discussed, answering the question of how meaning is derived from touch requires a complex answer.

A Proposed Model of Tactile Communication

I propose a model of tactile communication in figure 1 taking into account the available empirical evidence on touch, as well as the conceptual framework discussed in this article. To be sure, the model is preliminary considering the fact that there is so little empirical research on which to draw. Nevertheless, I construct the model as a heuristic that may help us conceptualize the domain of tactile communication.

Two caveats must be made before discussing the model. First, I have provided empirical evidence and argued that touch plays a unique and independent role in the infant-caregiver communication system. However, the tactile stimulation that the infant receives transpires within the context of a larger infant-caregiver communication system comprised of several modalities. This fact must not be ignored if we are going to understand the infant-caregiver communication system as an integrated whole.

Second, the caregiver-infant communication system is a dynamic and joint venture in which there is mutual regulation [Fogel & Lyra, 1997; Tronick, 1989]. The bi-directional and relational nature of communication is readily apparent in the tactile modality, for one cannot touch without being touched, a point already mentioned [Merleau-Ponty, 1962]. The infant is not a passive recipient of touch, but takes an active role in the communication process. The model of tactile communication that I propose should not be viewed as residing solely within the infant or within the caregiver, but squarely at the intersection between the two. Nevertheless, I have attempted to be analytic in the hope that doing so would allow us to better understand tactile communication as a whole.

The left column of the model refers to the qualities and parameters of touch that are administered to the infant. Recall that the qualities include the action, intensity, velocity, abruptness, and temperature of the touch while the parameters of touch include its location, frequency, duration, as well as the extent of the surface area touched, together constituting a complex tactile gestalt.

The stimulus array is given meaning by the infant in relation to the context in which the infant finds herself embedded; context is the mortar of caregiver-infant communication and, as such, is of instrumental value in helping the infant gain meaning from touch. The context in which touch is administered can profoundly influence the communicative functions of touch. For example, stroking a child's back immediately after a threatening event likely has a different meaning compared to the administration of the same tactile stimulus immediately after the child has just completed a task successfully.

There are a number of factors and variables that comprise the context in which touch occurs. The other modalities that the caregiver uses to communicate with the infant likely contextualize tactile stimulation (e.g., the caregivers' facial and vocal displays). Sources beyond immediate stimulation like the broad social, economic, and historical ecology within which the infant is embedded are also likely to influence the meaning of tactile stimulation. Furthermore, the events preceding (both immediately

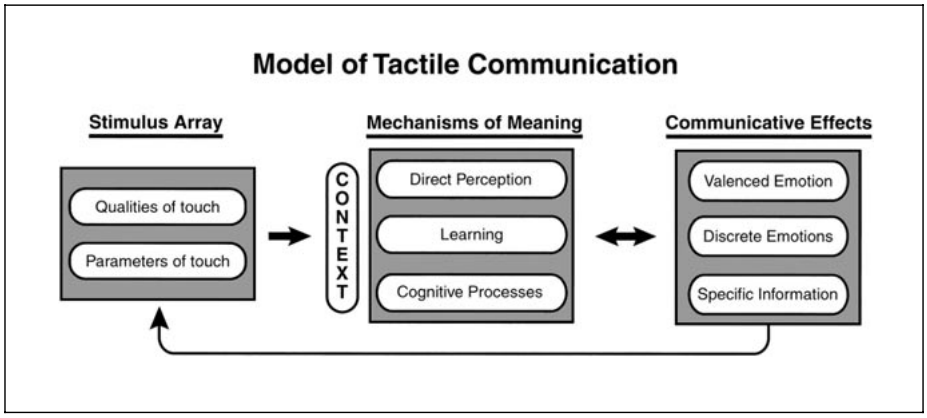

Fig. 1. Model of tactile communication.

and far in advance) an episode of tactile communication likely influence the ultimate meaning of touch. For example, as mentioned, Peláez-Nogueras et al. [1996a] found that infants of depressed mothers reacted more positively to touch administered to them during the still-face paradigm than infants of nondepressed mothers.

Contextual factors act as a 'filter' for the mechanisms by which touch gains meaning for the infant. Three potential mechanisms of meaning were discussed: direct perception, learning, and cognitive processes. These mechanisms, in conjunction with tactile stimulation and context, result in the varying communicative effects of touch. The three communicative functions of touch discussed in this article – valenced emotion, discrete emotions, and specific information – are not meant to exhaust the other communicative functions that touch may serve (e.g., mood, state regulation).

As mentioned, the proposed model of tactile communication is bi-directional and dynamic. The ultimate communicative effects of touch feed back to the qualities and parameters of touch that the infant will likely experience in the future. For example, if a sensitive caregiver administers a form of touch that communicates to the infant in a desired manner, the caregiver is likely to administer the same or similar form of touch (in context) in the future. In contrast, if the caregiver's touch does not have the desired communicative effect, her or she may be more likely to administer a different form of touch in the future. Thus, the effect(s) that touch has on the infant affects the qualities and parameters of touch that the infant will receive in the future from the caregiver.

Infants certainly differ in the quality and parameters of touch that they experience, as well as the context in which they find themselves. For example, Eibl-Eibesfeldt [1989] has reported that mothers stroke the genitals of their children as a gesture of affection in many tribal societies – a major qualitative and parametric difference compared to infants in many other cultures. As another example, infants in the Efe and !Kung tribes are touched much more compared to infants in the West [Konner, 1976; Tronick, 1995].

Individual differences are also likely in the mechanisms that infants use to gain meaning from touch (thereby resulting in differences in the communicative effects of touch). The same tactile stimulus array in the same context can serve very different communicatory functions for one infant versus another.

Little data exist documenting the biological and environmental factors (and the interaction between the two) that influence the communicative effects of touch. Infant temperament and central nervous system development are prime biological candidates that may account for individual differences in the communicative effects of touch. Als and her colleagues [1986] have found that very low birth weight preterm infants have a diminished ability to regulate their responses to touch as a function of their fragile nervous systems. Others have found that preterm infants have a lower threshold for touch and find some types of touch aversive [e.g., Anderson, 1986]. In addition to biological factors, infants' general interactional histories (including their history of tactile stimulation) and contextual factors most likely influence individual differences in the communicative effects of touch. Recall Peláez-Nogueras et al.'s [1996a] findings that infants of depressed mothers displayed more positive emotion in the presence of a still-face than infants of non-depressed mothers.

The empirical soundness of the model can only be addressed by careful research that describes both the communicative functions of touch and investigates the mechanisms that underlie these effects.

Future Directions

Perhaps the two most fundamental questions that deserve attention are the ones on which this article has focused: *what* is communicated to infants through touch and *how* does meaning come about from touch?

There are a number of steps that will help us tackle these questions. First, researchers must develop reliable coding systems to investigate the qualities and parameters of touch that caregivers administer to their infants. To date, no tactile coding systems are published, making it difficult for researchers to study touch.

The second step is to gather descriptive data regarding when and how caregivers (both mothers and fathers) use touch to communicate with their infants. We know little about how adults touch their infants over the first two years of life; a developmental analysis of touch patterns used by adults is definitely warranted. Such an analysis will not only help us identify how and when caregivers use touch, but will also help us discover the individual differences in infant's tactile lives. Related to this point, pancultural descriptive studies of touch would be very illuminating as they would uncover both the universal and culturally specific qualities and parameters of tactile stimulation in the infant-caregiver dyad.

Third, studies are needed that identify functional relations between tactile stimulus arrays and infants' behaviors in real-time, especially their emotional displays. Fourth, longitudinal studies examining the effects of touch on infants' long-term socio-emotional development are needed. To date, longitudinal studies have focused almost completely on massage therapy and its effects over time. While these studies are of instrumental importance, investigations are required to examine how touch outside of the therapeutic domain influences the infant over time.

Fifth, investigations should be conducted to understand what happens when the 'message' that the caregiver attempts to communicate via touch is not properly interpreted by the infant. 'Mismatches' of communication likely influence infants' immediate behaviors as well as their long-term socio-emotional development [Tronick, 1989]. Finally, the mechanisms by which touch gains meaning for the infant merit attention. Like most investigations in the social sciences, it is likely that studies of mechanism will come after much of the descriptive work has been carried out.

Two important points should be kept in mind regarding the directions that I have outlined for future investigation. First, touch should be placed in the context of infant-caregiver relationships comprised of multimodal communication. When one focuses on a single modality – in this case, touch – one runs the risk of not understanding the infant-caregiver communication system for what it is: an inherently seamless and dynamic process that is characterized by bi-directionality, as well as developmental change and stability. Second, there is a clear need in the field of touch (in other fields as well) for converging research operations so we can be more confident about the inferences we draw about the communicative functions of touch on infants. Isolating the effects of touch are difficult (and may not be desirable); only with converging research operations can we draw inferences about the communicative effects of touch with confidence.

The embryonic field of tactile communication has yet to develop into a coherent and systematic research enterprise. It is ironic that touch may represent one of the most fundamental means by which caregivers communicate with their infants and, yet, it has been overlooked by the vast majority of researchers interested in communication. I hope the present article will provide an impetus to study touch and its communicative functions across a variety of disciplines and levels of analysis.

Acknowledgment

Matthew J. Hertenstein, Department of Psychology, University of California, Berkeley. The writing of this article was supported by a NRSA fellowship from NIMH (MH-12320). I thank Joseph Campos, Sandra Weiss, three reviewers, and several others for their valuable comments on earlier versions of this article.

References

Ainsworth, M.S., Blehar, M.C., Waters, E., & Wall, S. (1978). *Patterns of Attachment: A Psychological Study of the Strange Situation.* Hillsdale, NJ: Erlbaum.

Als, H., Lawhon, G., Brown, E., Gibes, R., Duffy, F.H., McAnulty, G., & Blickman, J.G. (1986). Individualized behavioral and environmental care for the very low birth weight preterm infant at high risk for bronchopulmonary dysplasia: Neonatal intensive care unit and developmental outcome. *Pediatrics, 78,* 1123–1132.

Andersen, P.A. (1991). When one cannot not communicate: A challenge to Motley's traditional communication postulates. *Communication Studies, 42,* 309–325.

Anderson, J. (1986). Sensory intervention with the preterm infant in the neonatal intensive care unit. *American Journal of Occupational Therapy, 40,* 19–26.

Anisfeld, E., Casper, V., Nozyce, M., & Cunningham, N. (1990). Does infant carrying promote attachment? An experimental study of the effects of increased physical contact on the development of attachment. *Child Development, 61,* 1617–1627.

Bandura, A. (1965). Influence of models' reinforcement contingencies on the acquisition of imitative responses. *Journal of Personality and Social Psychology, 1,* 589–595.

Barnett, K. (1972). A theoretical construct of the concepts of touch as they relate to nursing. *Nursing Research, 21,* 102–110.
Barrett, K.C., & Campos, J.J. (1987). Perspectives on emotional development. II. A functionalist approach to emotions. In J.D. Osofsky (Ed.), *Handbook of infant development* (2nd ed., pp. 558–578). New York: Wiley.
Barrett, K.C., & Nelson-Goens, G.C. (1997). Emotion communication and the development of the social emotions. In K.C. Barrett (Ed.), *The communication of emotion: Current research from diverse perspectives* (pp. 69–88): Jossey-Bass.
Bavelas, J.B. (1990). Behaving and communicating: A reply to Motley. *Western Journal of Speech Communication, 54,* 593–602.
Bowlby, J. (1969). *Attachment and loss, vol. 1, Attachment.* New York: Basic Books.
Bowlby, J. (1973). *Attachment and loss, vol. 2, Separation.* New York: Basic Books.
Bretherton, I., Biringen, Z., Ridgeway, D., & Maslin, C. (1989). Attachment: The parental perspective. Special Issue: Internal representations and parent-infant relationships. *Infant Mental Health Journal, 10,* 203–221.
Brossard, L., & Decarie, T. (1968). Comparative reinforcing effects of eight stimulations on the smiling responses of infants. *Journal of Child Psychology and Psychiatry, 9,* 51–60.
Buck, R. (1988). The perception of facial expression: Individual regulation and social coordination. In T.R. Alley (Ed.), *Social and applied aspects of perceiving faces* (pp. 141–165). Hillsdale, NJ: Erlbaum.
Bushnell, E.W., & Baxt, C. (1999). Children's haptic and cross-modal recognition with familiar and unfamiliar objects. *Journal of Experimental Psychology: Human Perception & Performance, 25,* 1867–1881.
Bushnell, E.W., & Bourdreau, J.P. (1991). The development of hepatic perception during infancy. In M.A. Heller & W. Schiff (Eds.), *The psychology of touch* (pp. 139–161). Hillsdale, NJ: Erlbaum.
Campos, J.J., Barrett, K.C., Lamb, M.E., Goldsmith, H.H., & Stenberg, C. (Eds.). (1983). *Socio-emotional development* (Vol. 2). New York: Wiley.
Campos, J.J., Mumme, D.L., Kermoian, R., & Campos, R. (1994). A functionalist perspective on the nature of emotion. *Monographs of the Society for Research in Child Development, 59,* 284–303.
Cannon, R.B. (1977). The development of maternal touch during early mother-infant interaction. *Jogn Nursing, 6,* 28–33.
Clynes, M. (1977). *Sentics: The touch of emotions.* New York: Anchor Press.
Cohn, J.F., & Tronick, E. (1989). Specificity of infants' response to mothers' affective behavior. *Journal of the American Academy of Child & Adolescent Psychiatry, 28,* 242–248.
Dickson, K.L., Fogel, A., & Messinger, D. (1998). The development of emotion from a social process view. In M.F. Mascolo & S. Griffin (Eds.), *What develops in emotional development?* (pp. 253–271). New York: Plenum Press.
Dickson, K.L., Walker, H., & Fogel, A. (1977). The relationship between smile type and play type during parent-infant play. *Developmental Psychology, 33,* 925–933.
Eibl-Eibesfeldt, I. (1989). *Human Ethology.* New York: Aldine de Gruyter.
Ekman, P. (1999). Facial expressions. In T. Dalgleish & M.J. Power (Eds.), *Handbook of cognition and emotion* (pp. 301–320). Chichester, England: Wiley.
Fantz, R.L. (1961). The origin of form perception. *Scientific American, 204,* 66–72.
Field, T., Healy, B.T., Goldstein, S., & Guthertz, M. (1990). Behavior-state matching and synchrony in mother-infant interactions of nondepressed versus depressed dyads. *Developmental Psychology, 26,* 7–14.
Field, T.M. (1998). Massage therapy effects. *American Psychologist, 53,* 1270–1281.
Fogel, A., & Lyra, M.C.D.P. (1997). Dynamics of development in relationships. In F. Masterpasqua & P.A. Perna (Eds.), *The psychological meaning of chaos: Translating theory into practice* (pp. 75–94): Washington, DC, US.
Frank, L.K. (1957). Tactile communication. *Genetic Psychology Monographs, 56,* 209–255.
Frijda, N.H. (1986). *The emotions*. Cambridge, England: Cambridge University Press.
Geldard, F.A. (1960). Some neglected possibilities of communication. *Science, 131,* 1583–1588.
Gibson, E.J. (1969). *Principles of Perceptual Learning and Development.* East Norwalk, CT: Appleton-Century-Crofts.
Gibson, J.J. (1996). *The senses considered as perceptual systems.* Boston: Houghton Mifflin.
Gibson, J.J. (1979). *The ecological approach to visual perception.* Boston: Houghton Mifflin.
Greenoug, W.T. (1990). Brain storage of information from cutaneous and other modalities in development and adulthood. In K.E. Barnard & T.B. Brazelton (Eds.), *Touch: The foundation of experience: Full revised and expanded proceedings of Johnson & Johnson Pediatric Round Table X* (pp. 97–126). Madison, CT: International Universities Press.
Hebb, D.O. (1946). On the nature of fear. *Psychological Review, 53,* 259–276.
Hertenstein, M.J., & Campos, J.J. (in press). Emotion regulation via maternal touch. *Infancy.*
Hinde, R.A. (1997). *Relationships: A dialectical perspective*. Hove: Psychology Press.
Izard, C.E. (1979). *The maximally discriminative facial movement coding system (Max).* Newark, DE: University of Delaware, Instructional Resources Center.
Kagan, J. (1971). *Change and continuity in infancy.* New York: Wiley.
Knapp, M.L. (1984). *Interpersonal communication and human relationships.* Boston: Allyn & Bacon.
Konner, M.J. (1976). Maternal care, infant behavior and development among the !Kung. In R.B. Lee & I. DeVore (Eds.), *Kalahari hunger-gatherers: Studies of the !Kung San and their neighbors* (pp. 218–245). Cambridge, MA: Harvard University Press.

Landau, R. (1989). Affect and attachment: Kissing, hugging, and patting as attachment behaviors. *Infant Mental Health Journal, 10,* 57–69.
Levenson, R.W. (1992). Autonomic nervous system differences among emotions, *Psychological Science, 3,* 23–27.
Lorenz, C. (1943). Die angeborenen Formen möglicher Erfahrung. *Zeitschrift für Tierpsychologie, 5,* 233–409.
Main, M. (1990). Parental aversion to infant-initiated contact is correlated with the parent's own rejection during childhood: The effects of experience on signals of security with respect to attachment. In K.E. Barnard & T.B. Brazelton (Eds.), *Touch: The foundation of experience: Full revised and expanded proceedings of Johnson & Johnson Pediatric Round Table X. Clinical infant reports* (pp. 461–495). Madison, CT: International Universities Press.
Main, M., Kaplan, N., & Cassidy, J. (1985). Security in infancy, childhood, and adulthood: A move to the level of representation. *Monographs of the Society for Research in Child Development, 50,* 66–104.
Main, M., & Stadtman, J. (1981). Infant response to rejection of physical contact by the mother. *Journal of the American Academy of Child Psychiatry, 20,* 292–307.
Major, B. (1981). Gender patterns in touching behavior. In C. Mayo & N.M. Henley (Eds.), *Gender and nonverbal behavior* (pp. 15–37). New York: Springer-Verlag.
Maurer, D., & Maurer, C. (1988). *The world of the newborn.* New York: Basic Books.
Merleau-Ponty, M. (1962). *Phenomenology of perception* (Colin Smith, Trans.). New York: Humanities Press.
Montagu, A. (1986). *Touching: The human significance of the skin.* (3rd ed.). New York: Harper & Row.
Motley, M.T. (1990a). Communication as interaction: A reply to Beach and Bavelas. *Western Journal of Speech Communication, 54,* 613–623.
Motley, M.T. (1990b). On whether one can(not) communicate: An examination via traditional communication postulates. *Western Journal of Speech Communication, 54,* 1–20.
Motley, M.T. (1991). How one may not communicate: A reply to Andersen. *Communication Studies, 42,* 326–329.
Oster, H. (2001). *Baby FACS: Facial Action Coding System for Infants and Young Children.* Unpublished monograph and coding manual, New York University.
Peláez-Nogueras, M., Field, T., Gewirtz, J.L., Cigales, M., Gonzalez, A., Sanchez, A., & Richardson, S.C. (1997). The effects of systematic stroking versus tickling and poking on infant behavior. *Journal of Applied Developmental Psychology, 18*, 169–178.
Peláez-Nogueras, M., Field, T.M., Hossain, Z., & Pickens, J. (1996a). Depressed mothers' touching increases infants' positive affect and attention in still-face interactions. *Child Development, 67,* 1780–1792.
Peláez-Nogueras, M., Gewirtz, J.L., Field, T., & Cigales, M. (1996b). Infants' preference for touch stimulation in face-to-face interactions. *Journal of Applied Developmental Psychology, 17,* 199–213.
Piaget, J. (1952). *The origins of intelligence in children.* New York: International Universities Press.
Reite, M. (1990). Touch, attachment, and health: Is there a relationship? In K.E. Barnard & T.B. Brazelton (Eds.), *Touch foundation of experience: Full revised and expanded proceedings of Johnson & Johnson Pediatric Round Table X* (pp. 195–225): Madison, CT.
Rose, S.A., & Ruff, H.A. (1987). Cross-Modal Abilities in Human Infants: In J.D. Osofsky (Ed.), *Handbook of infant development* (2nd ed., pp. 318–362). Oxford, England: Wiley.
Scherer, K.R. (1986). Vocal affect expression: A review and a model for future research. *Psychological Bulletin, 99,* 143–165.
Sroufe, L.A. (1996). *Emotional development: The organization of emotional life in the early years.* New York: Cambridge University Press.
Stack, D.M. (in press). The salience of touch and physical contact during infancy: Unraveling some of the mysteries of the somaesthetic sense. In A. Fogel & G. Bremner (Eds.), *Blackwell handbook of infant development.* London: Blackwell.
Stack, D.M., & Arnold, S.L. (1998). Changes in mothers' touch and hand gestures influence infant behavior during face-to-face interchanges. *Infant Behavior & Development, 21,* 451–468.
Stack, D.M., & LePage, D.E. (1996). Infants' sensitivity to manipulations of maternal touch during face-to-face interactions. *Social Development, 5,* 41–55.
Stack, D.M., LePage, D.E., Hains, S.M.J., & Muir, D.W. (2001). *Differential touch as a function of instruction during mother-infant interactions: Application of the caregiver-infant touch scale (CITS).* Unpublished manuscript, Concordia University.
Stack, D.M., & Muir, D.W. (1990). Tactile stimulation as a component of social interchange: New interpretations for the still-face effect. *British Journal of Developmental Psychology, 8,* 131–145.
Stack, D.M., & Muir, D.W. (1992). Adult tactile stimulation during face-to-face interactions modulates five-month-olds' affect and attention. *Child Development, 63,* 1509–1525.
Stepakoff, S., Beebe, B., & Jaffe, J. (2000). *Mother-infant tactile communication at four months: Infant gender, maternal ethnicity, and maternal depression.* Poster presented at the International Conference on Infant Studies, Brighton, England.
Stern, D.N. (1985). *The interpersonal world of the infant.* New York: Basic Books.
Sternberg, R.J. (1996). *Cognitive psychology.* (2nd ed.). Fort Worth: Harcourt Brace College.
Tronick, E.Z. (1989). Emotions and emotional communication in infants. *American Psychologist, 44,* 112–119.
Tronick, E.Z. (1995). Touch in mother-infant interaction. In T.M. Field (Ed.), *Touch in early development* (pp. 53–65). Mahwah, NJ: Erlbaum.

Tronick, E.Z., Als, H., Adamson, L., Wise, S., & Brazelton, T.B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of American Academy of Child Psychiatry, 17,* 1–13.

Walker-Andrews, A.S. (1997). Infant's perception of expressive behaviors: Differentiation of multimodal information. *Psychological Bulletin, 121,* 437–456.

Watzlawick, P., Beavin, J.H., & Jackson, D.D. (1967). *Pragmatics of human communication: A study of interactional patterns, pathologies, and paradoxes.* New York: W.W. Norton.

Weiss, S.J. (1990). Parental touching: Correlates of a child's body concept and body sentiment. In K.E. Barnard & T.B. Brazelton (Eds.), *Touch: The foundation of experience: Full revised and expanded proceedings of Johnson & Johnson Pediatric Round Table X. Clinical infant reports* (pp. 425–459). Madison, CT: International Universities Press.

Weiss, S.J. (1992). Psychophysiologic and behavioral effects of tactile stimulation on infants with congenital heart disease. *Research in Nursing & Health, 15,* 93–101.

Weiss, S.J., & R. Campos, R. (1999). Touch. In C.A. Lindeman & M. McAthie (Eds.), *Fundamentals of contemporary nursing practice* (pp. 941–962). Philadelphia: W.B. Saunders Company.

Weiss, S.J., Wilson, O., Hertenstein, M.J., & Campos, R. (2000). The tactile context of a mother's caregiving: Implications for attachment of low birth weight infants. *Infant Behavior and Development, 23,* 91–111.

Weiss, S.J., Wilson, P., Seed, J., Paul, S.M. (in press). Early tactile experience of low birth weight children: Links to later mental health and social adaptation. *Infant and Child Development.*

Witherington, D.C., Campos, J.J., & Herteinstein, M.J. (in press). Principles of emotion and its development in infancy. In A. Fogel & G. Bremner (Eds.), *Blackwell handbook of infant development.* London: Blackwell.

Wolff, P.H. (1963). Observations on the early development of smiling. In B.M. Foss (Ed.), *Determinant of infant behavior II* (pp. 113–138). London: Methuen & Co.