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The Communicative Functions of Touch in Humans, Nonhuman Primates, and Rats: A Review and Synthesis of the Empirical Research

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ABSTRACT. Although touch is one of the most neglected modalities of communication, several lines of research bear on the important communicative functions served by the modality. The authors highlighted the importance of touch by reviewing and synthesizing the literatures pertaining to the communicative functions served by touch among humans, nonhuman primates, and rats. In humans, the authors focused on the role that touch plays in emotional communication, attachment, bonding, compliance, power, intimacy, hedonics, and liking. In nonhuman primates, the authors examined the relations among touch and status, stress, reconciliation, sexual relations, and attachment. In rats, the authors focused on the role that touch plays in emotion, learning and memory, novelty seeking, stress, and attachment. The authors also highlighted the potential phylogenetic and ontogenetic continuities and discussed suggestions for future research.

Key words: emotion communication, physical contact, touch.

THE STUDY OF THE COMMUNICATIVE FUNCTIONS OF TOUCH has received increasing attention over the past 3 decades. However, there is no comprehensive review that synthesizes our current knowledge of the communicative functions of touch for humans, nonhuman primates, and rats. This is despite the fact that touch is ubiquitous within each of these groups, funda-

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mental across the lifespan, and important for a number of cognitive and social functions.

Touch, as well as other means of nonverbal communication, is thought to have phylogenetic and ontogenetic primacy (Burgoon, Buller, & Woodall, 1996). *Phylogenetic primacy* means that, in the evolutionary history of our species, nonverbal communication, including touch, preceded language in evolutionary time (Dew & Jensen, 1977; Dunbar, 1996; McBride, 1975; McNeill, 1970). Burgoon et al. (1996) argued that people tend to rely more heavily on nonverbal communication, especially in times of stress, compared with verbal communication because of our evolutionary heritage.

Ontogenetic primacy means that, in the beginning of life, the importance of nonverbal communication, particularly tactile stimulation, supersedes that of verbal communication. Touch is the most developed sensory modality when the infant is born and it continues to play a fundamental role in communication throughout the first year of life (Field, 2001). In addition to the prevalence of holding, grasping, and nursing, infants develop a sense of space and time with repeated separations and contact from the caregiver (Burgoon et al., 1996). Thus, even before the child's first word is spoken, the groundwork for verbal communication has been laid by touch and other modalities of nonverbal communication.

In the present article, we first briefly discuss why the study of touch, compared with the study of other nonverbal modalities, has been relegated by researchers. Second, we discuss conceptual issues related to touch and communication, as well as the scope of the present review. Third, we synthesize the literature on the communicative functions of touch in humans, nonhuman primates, and rats. Throughout the article, we analyze the existing literature and provide suggestions for future research.

Touch: A Relegated Modality

Over 4 decades ago, Frank (1957) commented that the study of tactile communication was severely neglected. His comment still rings true today. As an index of the general interest among researchers to study touch, we conducted two sets of searches in psycINFO.[1] In the first set, we filtered the database for research on humans and conducted three searches for the following terms in the title: (a) *touch*, *physical contact*, or *tactile*; (b) *vision*, *sight*, or *visual*; and (c) *audition* or *hearing*. For the second set, we entered the same terms, but filtered for animals. As shown in Figure 1, across humans and animals, the study of vision exceeds that of touch by a 13:1 ratio. Moreover, the study of audition in humans outpaces the study of touch almost 3:1, whereas touch and audition are about equally studied in animals.

Why has the study of touch been neglected? The reasons stem from philosophy and methodology (Hertenstein, 2002). Since the time of Plato, Western philosophy has privileged the study of vision over other modalities. Descartes'

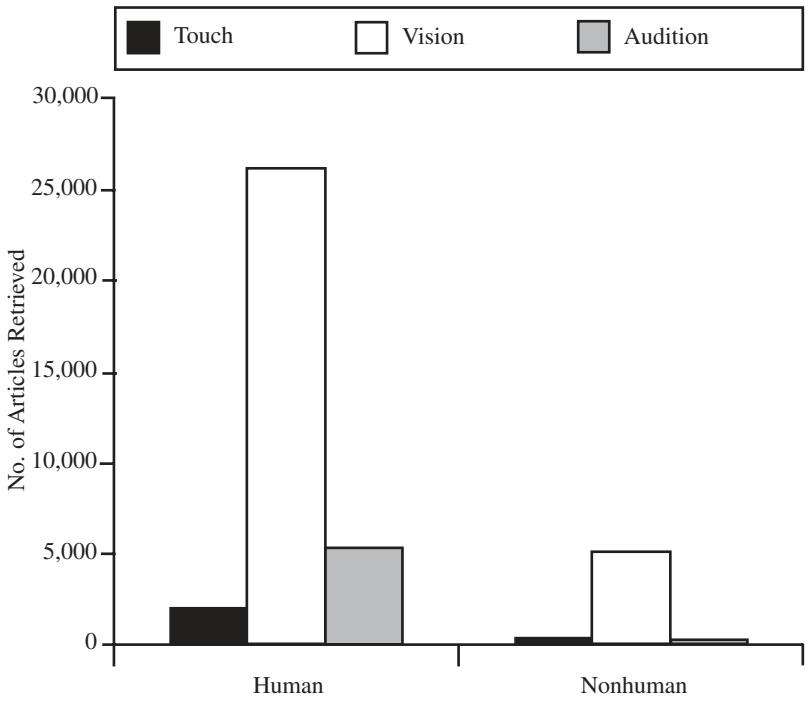

FIGURE 1. Number of articles retrieved in psychINFO relating to touch, vision, and audition.

(1637/1965) view is representative: "All the management of our lives depends on the senses, and since that of sight is the most comprehensive and the noblest of these, there is no doubt that the inventions which serve to augment its power are among the most useful that there can be" (p. 65). This view is likely responsible, at least in part, for the denigration of the other nonvisual modalities, including touch.

There are several methodological reasons that have impeded the study of touch. First, much tactile interaction takes place in privacy, making it difficult and, sometimes, inaccessible for researchers to study. Second, touch is difficult to measure because of its inherent complexity. Touch can vary in its action (e.g., rubbing, stroking, patting, pinching), intensity, velocity, abruptness, temperature, location, frequency, duration, and extent of surface area touched (Hertenstein, 2002). In fact, Morris (1971) identified 457 different types of body contact in one field study. Finally, proscriptions against touch among humans make it exceedingly difficult to study in the laboratory context (Major, 1981).

Conceptual Issues

It is prudent to present the definitions of the two major concepts in this article—touch and communication—as well as provide some principles that guided our literature review. Our conceptualization of touch and communication necessarily drove the content and approach of our review. We draw heavily on previous articles that outlined our definitional and theoretical orientation to the study of touch (Hertenstein, 2002; Hertenstein & Campos, 2001).

In the present article, we focus on two broad phenomena—touch and communication. The word *touch* is semantically rich as evidenced by the fact that the Oxford English Dictionary has dedicated hundreds of lines to defining the term (Reite, 1990). *Touch* can refer to two highly dissociable phenomena.[2] The first refers to the action of an object on the skin and the second refers to the registration of information by the sensory systems of the skin (i.e., feeling). The pressure exerted on the skin would encompass the former sense of the word, while feeling ticklish would be an aspect of the latter sense of the word (i.e., sensory registration).

The relations between touch and communication are very different depending on the aspect of touch to which one refers. For instance, a person may caress two people using the same quality of touch on the same location of the body (i.e., in the former sense of touch), yet only one of the people may perceive the touch positively while the other perceives it negatively. The stimulus pattern presented to a person and what people perceive are not isomorphic. To help clarify this distinction in the present article, we use the words *touch*, *tactile stimulus*, and *tactile pattern* in reference to the action of a touch on the skin and *feel* in reference to the sensory reception of touch.

In addition to presenting our conceptualization of touch, we must also define *communication*. Researchers have conceptualized communication in a wide variety of ways that differ between fields (e.g., sociobiology, ethology, sensory ecology, cognitive psychology, social psychology) and even within fields. In the present article, we draw from the ethological, functionalist, and nonverbal communication literatures that emphasize the behavioral and cognitive consequences of communication, rather than information transfer between two conspecifics. Thus, tactile communication occurs when there are systematic changes in another's perceptions, thoughts, feelings, or behavior as a function of another's touch in relation to the context in which it occurs (Hertenstein, 2002). This interaction is almost always bidirectional and contingent (Muir, 2002).

The definition we provide is broad in scope and refers to two dissociable aspects of communication. First, touch may transmit one's perceptions, thoughts, and feelings to another. For example, a person may communicate love to another person by caressing that individual on the cheek. In contrast, the second facet of communication does not require that one person's perceptions, thoughts, or feelings be transmitted to another. Instead, someone's perceptions, thoughts,

feelings, or behaviors may be regulated by touch from another. For example, people may simply elicit a positive emotion in others without actually experiencing the emotion themselves. In the present article, we refer to both of these facets as *communication*.

There are two broad approaches to the study of tactile communication (Burgoon et al., 1996). The structural approach, prevalent in the human literature, emphasizes the meaning(s) assigned to particular types of touch (e.g., shove, kick, pat) or dimensions of touch (e.g., duration, frequency, intensity). In contrast, functional approaches to the study of touch, prevalent in both human and animal literatures, focus on the purposes and consequences of touch rather than the meanings assigned to specific types of touch. In the current review, we draw on both of these approaches to the study of touch, but emphasize the functional consequences of touch.

There are three important points that must be made regarding communication in general and touch specifically. The first involves intentionality. There has been a longstanding debate amongst theoreticians about whether or not the intentionality of touch should be a criterion for true communication (Hinde, 1997; Knapp, 1984; Watzlawick, Beavin, & Jackson, 1967). Some hold that behavior must be intentionally displayed (i.e., deliberate) and be goal directed for true communication (e.g., Watzlawick et al.), whereas others hold that intention should not be used as a criterion for communication (e.g., Hinde). The position we take aligns with the latter conceptualization, indicating that touch need not be intentional to be considered communication.

The second point involves the principles of equifinality and equipotentiality. The *principle of equifinality* refers to the idea that the same communicative outcome can be achieved via a number of different means (e.g., anger may be communicated via a slap or a push). The *principle of equipotentiality* refers to the idea that the same type of touch can be assigned very different meanings or consequences (e.g., an arm around one's shoulders interpreted as loving or a display of dominance). When looking at the literature as a whole, it is clear that both equifinality and equipotentiality operate in the communication of touch (as they do in almost every modality of communication).

Finally, because communication always occurs in a context, it is almost never unimodal, and is bidirectional (Burgoon et al., 1996; Field, 2001; Hertenstein, 2002; Montagu, 1986; Stack, 2001). When discussing any particular communicative modality, be it vision, audition, or touch, one must remain mindful that all communication is surrounded by a local context and larger historical, social, and economic context (Bronfenbrenner & Morris, 1998). Moreover, other modalities typically covary with others during the communication process, so researchers need to take great care when focusing on only one modality to the exclusion of the others. In addition, all communication is bidirectional; there is a constant interplay between communicators, and each affects the others' communicative signals.

Content of the Review

As previously mentioned, the purpose of this review is to bring together the extraordinarily diverse range of research on the communicative functions of touch among conspecifics in humans, nonhuman primates, and rats.[3] We chose to focus on the functions served by touch as they relate to social phenomena primarily and cognition secondarily. As in all literature reviews, difficult decisions must be made regarding the best way to parse the literature; our review is no different. The vast majority of the studies we reviewed fell within the purview of core social and cognitive phenomena, which we used to organize our article. We recognize that the domains we have chosen are not necessarily orthogonal to each other.

Our goal in this article is not to review 100% of the functions served by touch, but rather to review the core communicative functions on which investigators have focused. Reviewing domains in which there is considerable empirical data allowed us to be more confident in our conclusions. We decided not to focus on some functions of touch simply because the functions have received little attention from investigators (e.g., how infants use touch to communicate with caregivers). In other cases, we decided against inclusion of functions because investigators made little or no attempt to understand the unique contributions of the tactile modality, but instead considered it within the larger context of communication (e.g., studies focusing on the effects of stimulus deprivation, including touch, on infants [Spitz & Wolf, 1946]). Thus, we did not review research domains in which investigators conducted too few or methodologically inadequate studies to militate against understanding the unique contributions of touch.

Whether readers find the current review comprehensive or even representative will depend on the theoretical orientation(s) they adopt, as well as where they draw the line on the previously discussed issues of touch and communication. Readers will surely construct alternative conceptualizations of the chosen communicative functions of touch and point to absent publications that they would have included; this review is limited to the extent that it has missed such domains and studies.

TOUCH IN HUMANS

Touch in Infancy

The importance of touch in infancy cannot be overstated. Touch is one of the first functional modalities to mature in the infant, and it continues to play a fundamental role throughout the infant's life (Rubin, 1963). Touch regulates physiological states, aids normal biological development, and plays a central part in social development (Montagu, 1986). Given the early development of the tactile system, as well as touch's central role in early life, touch may very well establish the foundation of all other forms of communication developed later in life.

In the present section, we discuss the role of touch in emotional communication, attachment, and bonding.[4] Table 1 shows the empirical studies that focus

TABLE 1. Studies of Tactile Communication in Humans Classified According to Methodology, Participants, and Examined Variables

Author	Study type	Participants	Variable
Aguilera (1967)	Experimental	31 patients admitted to hospital	Effect of touch on verbal interaction and attitude between nurses and patients
Ainsworth et al. (1978)	Observational	23 infants (aged 3 to 54 weeks)	Maternal interaction and attachment style
Andersen & Sull (1985)	Experimental & Self-Report	48 undergraduates (25 women and 23 men)	Effect of touch avoidance on interpersonal distance
Anisfeld et al. (1990)	Experimental	49 infants (aged 3.5 and 13 months) and their mothers	Effect of physical contact on infant attachment
Argyle & Dean (1965)	Experimental	6 adults and 6 children	Eye contact and equilibrium for distance
	Experimental	80 subjects, 24 in the main experiment (half women and half men)	Effect of distance on eye contact
Beier & Sternberg (1977)	Interview & Observational	51 recently married couples	Touch, nonverbal communication, and martial adjustment
Bowen & Miller (1980)	Observational	46 fathers of neonates	Effect of paternal presence in delivery room on attachment behavior toward infant
Brockner et al. (1982)	Experimental	64 women and 64 men (estimated average age 30–35)	Effect of eye contact, touch, and sex on compliance
Brossard & Decarie (1968)	Experimental	32 infants (aged 16–20 wks)	Effect of stimulus patterns, including touch, on infant affect
Burgoon et al. (1984)	Experimental	150 undergraduates	Effect of nonverbal behaviors on relational messages
Burgoon et al. (1992)	Experimental	78 undergraduates (36 women and 36 men)	Effect of touch and valence on evaluations and attractiveness ratings
Crusco & Wetzel (1984)	Experimental	114 diners (35 women and 79 men)	Effect of interpersonal touch on restaurant tipping
De Chateau & Wiberg (1977)	Experimental & Interview	38 mother-infant dyads (aged 36 hours and 3 months)	Effect of extra postpartum contact on mother-on-infant behavior

(table continues)

TABLE 1. ***Continued***

Author	Study type	Participants	Variable
Dibiase & Gunnoe (2004)	Observational	40 Italians (20 women and 20 men), 40 Czechs (20 women and 20 men), and 40 Americans (20 women and 20 men, all people judged to be in early or mid-20s)	Gender and culture in touching behavior
Dickson et al. (1997)	Observational	36 infants (aged 1 year) and their mothers and fathers	Effects of parental play-type on infant smile-type
Emmers & Dindia (1995)	Self-Report	135 undergraduate opposite-sex couples	Effect of relational stage and intimacy on touch
Fisher et al. (1976)	Experimental	101 undergraduates (52 men and 49 women)	Effect of touch, sex of experimenter, and sex of subject on affect and liking
Foehl & Goldman (1983)	Experimental	40 women and 40 men (judged to be under the age of 60)	Effect of face and foot procedures on altruistic behavior
	Experimental	30 women and 30 men (under the age of 60)	Effect of face and foot procedures on altruistic behavior
Goldman & Fordyce (1983)	Experimental	81 women and 79 men (walking on a college campus)	Effect of eye contact, touch, and voice expression on helping behavior
Goldman et al. (1985)	Experimental	120 people (mostly undergraduates)	Effect of touch on compliance
Goldstein & Jeffords (1981)	Observational	State legislators	Status, age and touching behavior
Gray et al. (2000)	Experimental	30 neonates (aged 33–55 hours) and their mothers	Effects of maternal touch on infant grimacing and crying
Gray et al. (2002)	Experimental	30 neonates (aged 33–55 hours) and their mothers	Effects of breastfeeding on infant grimacing and crying
Grossman et al. (1981)	Experimental	54 German mother-infant dyads (aged 1 hour–10 days)	Effect of extended postpartum contact on maternal attachment behavior
Grusky et al. (1984)	Experimental	48 middle-SES families	Effect of status within family on initiated touch

(table continues)

TABLE 1. ***Continued***

Author	Study type	Participants	Variable
Gueguen (2002a)	Experimental	120 women and 120 men (aged 30–50 years)	Effect of touch and gender on compliance
Gueguen (2002b)	Experimental	90 women and 90 men (aged 30–50 years)	Effect of status and touch on compliance
Gueguen (2002c)	Experimental	241 women (aged 18–50 years)	Effect of touch and awareness of touch on compliance with a request
Gueguen (2004)	Experimental	38 women and 64 men (aged 18–20 years)	Effect of tactile contact between teacher and student on class participation
Gueguen & Fischer-Lokou (2003)	Experimental	43 women and 17 men	Effect of touch on helping behavior
Gueguen & Fischer-Lokou (2002)	Experimental	67 women and 53 men (judged to be 18–50 years)	Effect of touch on compliance to a large request
Guerrero & Andersen (1991)	Observational & Self-Report	154 opposite-sex couples	Relational stage, gender, and touch
Guerrero & Andersen (1994)	Observational & Self-Report	132 dating and married couples	Touch behavior and touch attitude
Hales et al. (1977)	Experimental	60 mothers and their newborns (aged 12 hours)	Postpartum contact and length of sensitive period
Hall (1996)	Observational	Professional conference attendees (studies 1, 2, and 3)	Touch, status, and gender
Hall & Friedman (1999)	Observational	22 women and 24 men (aged 25–64 years)	Effect of organizational status and gender on nonverbal behavior
Hall & Veccia (1990)	Observational	4,500 dyads (teenagers and older)	Effect of gender on touch initiation
Henley (1973)	Observational	People in public	Status variables and touch initiation
Hertenstein & Campos (2001)	Experimental	36 infants (aged 12 months)	Effect of maternal tactile stimulation on infant instrumental behaviors
Heslin & Boss (1980)	Observational & Self-Report	103 dyads at an airport	Touch and intimacy
Heslin et al. (1983)	Self-Report	208 undergraduates	Meanings of touch on various areas of the body from strangers and same sex persons

(table continues)

TABLE 1. ***Continued***

Author	Study type	Participants	Variable
Hewitt & Feltham (1982)	Experimental	54 undergraduates (26 women and 28 men)	Effect of touch type, sex of subject, and sex of experimenter on subject's biofeedback
Hornik (1991)	Experimental	286 shoppers (144 women and (144 men)	Effect of touch on shopping time and amount purchased
Hornik (1992)	Experimental	286 shoppers	Effect of touch, sex, and attractiveness on shopping time, store evaluation, and amount of purchase
	Experimental	248 mixed-couple diners	Effect of touch, gender, attractiveness on tipping
	Experimental	217 lone adult shoppers	Effect of touch and gender on tasting and purchasing request
Hornik and Ellis (1988)	Experimental	288 shoppers (144 women and 144 men)	Effect of gaze and touch on compliance for mall intercept interview
Jones (1986)	Log method	40 undergraduates (20 women and 20 men)	Sex differences in tactile communication
Jones & Yarbrough (1985)	Log method	17 men and 22 women (aged 20–24 years	Various types of tactile interaction
Jourard (1966)	Self-Report	140 women and 168 men (unmarried college students)	Body-accessibility
Jourard & Friedman (1970)	Experimental	48 undergraduates (24 women and 24 men)	Effect of distance on self-disclosure
	Experimental	100 undergraduates (50 women and 50 men)	Effect of distance on self-disclosure
Juni & Brannon (1981)	Experimental	165 undergraduates	Effect of status and sex on touch initiation
	Experimental	67 undergraduates	Effect of status and sex on touch initiation
Kaufman & Mahoney (1999)	Experimental	48 women and 96 men (aged 21–50 years	Effect of touch on alcohol consumption
Keller et al. (1985)	Self-Report & Experimental	34 fathers of neonates	Effect of extended contact on parenting behaviors

(table continues)

TABLE 1. ***Continued***

Author	Study type	Participants	Variable
Kennell et al. (1974)	Observational & Interview	28 primiparous mothers and their infants (aged 0–3 days, 1 month)	Effect of extended contact on maternal attachment behavior
Klaus et al. (1972)	Observational & Interview	28 primiparous mothers and their infants (aged 0–32 days)	Effect of extended contact on maternal behavior
Kleinke (1977)	Experimental	53 men	Effect of gaze and touch on compliance
	Experimental	88 women and 90 men	Effect of gaze and touch on compliance
Kontos (1978)	Experimental	48 infants (aged 0, 1, 3, months) and their mothers	Effect of extended contact on maternal attachment
Lamb (1977)	Observational	20 infants (aged 7, 8, 12, and 13 months) and their parents	Differences between maternal-infant and paternal-infant interaction
Main & Stadtman (1981)	Observational	38 infants (aged 21 months) and their mothers	Effect of maternal aversion to physical contact on infant conflict behavior
	Observational	30 infants (aged 12 months)	Effect of maternal aversion to physical contact on infant conflict behavior in presense of stranger
	Observational	26 infant-mother dyads (during 1st year of life)	Effect of maternal aversion to physical contact on infant conflict behavior
Major et al. (1990)	Observational	People in public	Effects of setting, age, and gender on touch initiation
McDaniel & Andersen (1998)	Observational & interview	154 opposite-sex dyads from 26 nations	Tactile communication between cross-sex dyads
Nannberg & Hansen (1994)	Experimental	104 women and 94 men	Effect of touch on task performance
Nguyen et al. (1976)	Self-report	54 married and 52 unmarried college students	Different meanings of touch according to sex and martial status
Nguyen et al. (1975)	Self-report	81 undergraduates (40 women and 41 men)	Different meanings of touch according to sex

(table continues)

TABLE 1. ***Continued***

Author	Study type	Participants	Variable
Patterson et al. (1986)	Experimental	120 students (aged 18–20 years)	Effect of touch on compliance to help request
Paulsell & Goldman (1984)	Experimental	200 undergradates (100 women and 100 men	Effect of touching different body areas on helping behavior
Pelaez-Nogueras et al. (1997)	Experimental	12 infants (aged 2–4.5 months)	Effect of adult female's tactile behaviors (systematic stroking vs. tickling and poking) on infant's affective behavior and attention
Pelaez-Nogueras, Field, et al. (1996)	Experimental	48 depressed and nondepressed mothers and their infants (aged 3 months)	Effect of maternal touch on infant's affect and attention
Pelaez-Nogueras, Gewirtz, et al. (1996)	Experimental	10 infants (aged 1.5–3.5 months)	Effect of adult touch on infant affect and eye contact
Powel et al. (1994)	Experimental	236 undergraduates (135 women and 101 men)	Effect of timing of touch on compliance
Ringler et al. (1975)	Experimental	10 mothers and their infants (aged 2 years)	Effect of extra postpartum contact on maternal linguistic behavior
Ringler et al. (1978)	Experimental & Standardized tests	19 children (aged 2 and 5 years) and their mothers	Effect of maternal contact on speech patterns and IQs
Rodholm (1981)	Experimental	45 neonates (aged 24 hours) and their fathers	Effect of early contact on touching behavior 3 months later
Seashore et al. (1973)	Self-report	43 mothers of premature infants	Effect of extra contact on self-confidence
Silverthorne et al. (1976)	Experimental & Self-report	120 undergraduates (60 women and 60 men)	Effects of sex and initial touch on interpersonal judgment
Silverthorne et al. (1972)	Experimental	96 undergraduates (48 women and 48 men)	Effect of touch on aesthetic ratings
Smith et al. (1982)	Experimental	94 women and 42 men	Effect of touch on compliance to a marketing request

(table continues)

TABLE 1. ***Continued***

Author	Study type	Participants	Variable
Smith et al. (1980)	Observational	16 Black women, 15 Black men, 27 White women, 35 White men	Sex and racial differences in interpersonal touch
Stack & Arnold (1998)	Experimental	60 infants (aged 5.5 months) and their mothers	Effects of maternal touch and hand gestures on infant behavior
Stack & LePage (1996)	Experimental	48 infants (aged 5.5 months) and their mothers	Effects of maternal touch on infant's sensitivity to subtle changes
Stack & Muir (1990)	Experimental	50 infants (aged 3, 6, 9 months) and their mothers	Effect of maternal touch during still-face paradigm on infant affect and attention
	Experimental	16 infants (aged 3 and 6 months)	Effect of maternal touch during still-face paradigm on infant affect and attention (cross-sectional)
	Experimental	5 infants (aged 3 to 9 months)	Effect of maternal touch during still-face paradigm on infant affect and attention (longitudinal)
Stack & Muir (1992)	Experimental	9 infants (aged 5 months)	Effect of adult tactile stimulation on infant affect during SF paradigm
	Experimental	18 infants (aged 5 months)	Effect of adult tactile stimulation on infant affect during SF paradigm
	Experimental	20 infants (aged 5 months)	Effect of adult tactile stimulation on infant affect during SF paradigm
Stephen & Zweigenhaft (1986)	Experimental	112 pairs of customers (1 woman and 1 man in each pair)	Effect of waitress's touch on tipping from customers
Summerhayes & Suchner (1978)	Experimental	42 women and 18 men (students in natural science classes)	Effect of touch and status on perceived power in male-female relationships

(table continues)

TABLE 1. ***Continued***

Author	Study type	Participants	Variable
Sussman & Rosenfeld (1978)	Experimental	23 women and 21 men	Effect of touch, sex, and justification on aversiveness of spatial violations
	Experimental	40 women and 40 men	Effect of touch, sex, and justification on aversiveness of spatial violations
Svejda et al. (1980)	Experimental	30 primiparous mothers and their neonates (aged 0–3 days)	Effect of extra contact on mother-infant bonding
Weiss et al. (2000)	Observational & interview	131 low birth weight infants (aged 3 months, 6 months, and 1 year) and their mothers	Effect of maternal tactile behaviors on infant attachment
Weiss et al. (2001)	Questionnaire, observational, & interview	114 infants and their mothers	Maternal behaviors and infant mental health and social adaptation
Whitcher & Fisher (1979)	Experimental	29 women and 18 men (entered hospital for elective surgery)	Effect of sex and touch on subject's affect, behavior, and physiology
Willis & Briggs (1992)	Observational	696 opposite-sex dyads	Touch initiation among couples in public settings
Willis & Dodds (1998)	Observational & self-report	200 mixed-sex dyads	Age, gender, relationship, and touch initiation
Willis & Hamm (1980)	Experimental	320 undergraduates (160 women and 160 men)	Effect of gender and touch on compliance
	Experimental	128 women and 128 men (aged approx. 18–60 years)	Effect of gender and touch on compliance
Willis & Rawdon (1994)	Self-report	Men and women enrolled as undergraduates: 26 from Chile, 61 from Spain, 32 from Malaysia, 77 from United States	Gender and national differences in attitudes toward same-gender touch
Willis & Rinck (1983)	Log method	59 women and 17 men in psychology classes	Interpersonal touch in private settings
Wolff (1963)	Observational	8 infants (aged 0–30 days	Development of smiling in the first 30 days of life

Note. SES = socioeconomic status; SF = Still-Face.

on touch in humans. Although the literature on touch deprivation and massage therapy is important, it is beyond the scope of the present article (for an excellent review of the effects of massage therapy, see Field, 2001).

Touch and Emotional Communication

One of the areas that has received the most attention from researchers interested in touch is emotional communication (Peláez-Nogueras et al., 1997; Stack & Muir, 1990, 1992; Tronick, 1995). The term *emotion* is derived from the Latin "to move out," indicating that one facet of emotions is action and movement. Research indicates that touch from caregivers communicates emotion to infants by generating emotion in the infant or transferring the caregivers' emotional state to infants (Stack, 2001).

Hedonically valenced emotions may be communicated readily by touch (Hertenstein & Campos, 2001). The skin contains erogenous zones, as well as receptors that are nociceptive. In addition, infants are likely capable of associating different types of touch with environmental events, indicating that both positively and negatively valenced emotions may be communicated to infants (Hertenstein, 2002). Because hedonic processes are one of the primitives in the communication of emotion, touch is central to the study of emotion (Campos, Mumme, Kermoian, & Campos, 1994).

A host of studies indicate that touch communicates positive emotions and adds to the positive reinforcement value of other forms of stimulation (e.g., Peláez-Nogueras, Field, Hossain, & Pickens, 1996; Peláez-Nogueras, Gewirtz, et al., 1996; Wolff, 1963). Wolff, for example, showed that the game pat-a-cake, composed of tactile stimulation alone, was capable of generating positive emotions. Peláez-Nogueras, Gewirtz, et al. used a contingency-based technique to measure infants' preferences for social stimulation. The investigators used two sets of stimuli to reinforce infant eye contact to an experimenter: (a) a stimulus compilation that included the face, voice, and touch of an adult versus (b) one that did not include touch. Young infants who received touch displayed more smiles and vocalizations and spent less time crying than did infants receiving no touch. Other studies using this contingency method indicate that stroking elicits positive emotions and modulates negative ones compared with other forms of touch such as poking and tickling (Peláez-Nogueras et al., 1997).

Another set of studies using the still-face paradigm indicated that touch modulates negative emotions and generates positive ones (Peláez-Nogueras, Field, et al., 1996; Stack & Muir, 1990, 1992). In the still-face paradigm, infants are subjected to an adult's expressionless and stationary facial display while remaining silent, a condition that typically generates negative infant emotionality. Stack and Muir found that infants who are touched during the still-face paradigm, even if the infant's view of the mother's touching hands is obstructed, smile more and cry less compared with infants who are not touched.

Touch has also been shown to be an analgesic for infants (Gray, Miller, Philipp, & Blass, 2002; Gray, Watt, & Blass, 2000). Gray et al. (2000) studied 30 infants during a heel lance procedure, in which infants' heels are cut by doctors causing them to cry. Infants were randomly assigned to being either (a) held by their mothers in whole-body, skin-to-skin contact or to being swaddled in a crib during the procedure. Compared with the control condition, infants in the touch group cried 82% less, grimaced 65% less, and had a lower heart rate (Gray et al., 2000). Researchers found similar results when infants were given the heel lance procedure during breastfeeding (Gray et al., 2002).

Although touch is capable of generating positive emotions and modulating negative ones, it also is capable of generating negative emotions. This makes intuitive sense, although researchers have resisted focusing systematically on the relation between touch and negative emotionality, perhaps because of ethical reasons. One of the few studies of negative emotionality was conducted by Brossard and Decarie (1968), in which they found that static touch (simply laying a hand on infants' abdomens with little pressure) was less reinforcing and generated negative emotional displays compared with other stimuli that involved dynamic tactile stimulation.

Hertenstein and Campos (2001) showed that touch from mothers can generate negative emotional displays and can regulate infants' behaviors toward novel objects in the world. Twelve-month-old infants sat on their mothers' laps facing away while researchers serially presented novel objects to them. As each object was presented, the mothers administered tactile stimulation to their infants. In the negative tactile condition, the mother abruptly squeezed her infant while expanding her chest cavity silently against the infant's back. Compared with infants in the no-touch condition, infants receiving negative tactile communication waited longer to touch the objects, touched the objects less, and emoted more negatively.

Weiss, Wilson, Seed, and Paul (2001) demonstrated that harsh touch from mothers was associated with later emotional and behavioral problems. The touch that mothers used while feeding their 3-month-old infants was coded and analyzed in relation to infants' social adaptation and emotional or behavioral problems at 2 years of age. Infants who received harsher and more frequent touch at 3 months showed more aggressive and destructive behaviors than did those who received nurturing touch; those who received nurturing touch were less depressed and anxious compared with those who received harsh touch. Of course, this study should be interpreted with caution because of its correlational design.

To summarize, touch is central to the communication of emotion, particularly the hedonics of emotion. There is ample evidence indicating that infants are sensitive to subtle changes in the quality of touch they receive, perhaps meaning that distinct emotions are communicated to the infant in addition to hedonically valenced ones (Dickson, Walker, & Fogel, 1997; Stack & Arnold, 1998; Stack & LePage, 1996; Tronick, 1995). Data are needed to test this hypothesis.

Touch, Distress, and Attachment

Attachment researchers have long regarded the quality of parent-infant physical touch as a central feature of the responsive and available caregiving environment important in fostering an infant's sense of security (Ainsworth, Blehar, Waters, & Wall, 1978; Bowlby, 1973). According to Bowlby (1969), the attachment-behavioral system becomes activated when the infant is distressed because of any number of factors (e.g., separation from the caregiver, the dark, strangers). When the system becomes activated, the infant seeks proximity to the caregiver, often in the form of physical contact. Main (1990) suggested that physical contact with an attachment figure is the ultimate signal to infants that they are safe and secure from danger. If the infant is distressed, a sensitive caregiver 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 will do so awkwardly, and thus not convey security (Ainsworth et al.).

Converging evidence indicates that touch from the caregiver to the infant provides security and leads to a secure attachment relationship (Anisfeld, Casper, Nozyce, & Cunningham, 1990; Main, 1990; Main & Stadtman, 1981; Weiss, Wilson, Hertenstein, & Campos, 2000). In one experimental study, the investigators compared attachment outcomes for infants who were carried ventrally in soft infant carriers with those transported in harder infant seats (Anisfeld et al.). Infants carried in soft infant carriers were more likely to be judged secure than were those carried in infant seats. Such results indicate that security is communicated through touch (in this case, via soft infant carriers), although it is possible that mothers were more responsive to their infants' emotional signals while they were in the soft carriers, thereby mediating the effect of touch.

There is some evidence indicating that caregivers' aversion to contact, especially ventral-ventral contact, can have deleterious effects on the attachment relationship. In one sample of infants followed for the first year of life, Main and Stadtman (1981) found a significant relation between the mother's aversion to physical contact during the first quarter of the first year of life and displays of odd behavior by the infant (stereotypies, echoing speech, hand-flapping, and hair pulling) later in the first year.[5] In addition, infants whose mothers were touch-aversive displayed significantly more aggression and anger (e.g., hitting the mother) in the last quarter of the first year compared with mothers who were not touch-aversive.

To investigate relationships between touch and attachment, Weiss et al. (2000) observed mothers feeding their low-birth-weight infants at 3 months and coded maternal touch, maternal sensitivity, and infant responsiveness. At the end of infants' first year, investigators assessed infant security. The researchers found that robust low-birth-weight infants were more likely to establish a secure attachment when the mothers displayed nurturing touch; the sheer amount of physical contact displayed by mothers was not associated with individual differences

in attachment style. Ainsworth and her colleagues found similar results (Ainsworth et al., 1978). Although the duration of contact was not associated with individual differences in attachment, the quality of contact did make a difference; mothers who held their infants tenderly were more likely to have securely attached infants, whereas those who held their infants ineptly were more likely to have infants who were deemed insecurely attached. These studies emphasize that the presence of nurturing touch is not only important in the attachment relationship, but also paramount.

Bonding

In the late 1970s, parent-infant bonding in the period immediately following birth received significant attention (De Chateau & Wiberg, 1977; Grossman, Thane, & Grossman, 1981; Klaus, Kennell, Plumb, & Zuehlke, 1970; Lamb, 1977; Ringler, Trause, Klaus, & Kennell, 1978). Klaus, Kennell, and their colleagues conducted a longitudinal study with mothers and their infants that supported the idea that tactile contact during a critical period following birth was crucial to forming a loving bond between mothers and their newborns (Kennell et al., 1974; Klaus et al., 1972; Ringler, Kennell, Jarvella, Navojosky, & Klaus, 1975; Ringler et al., 1978). The investigators randomly assigned 28 mothers to an experimental group or a control group. The mothers in the experimental group were given their infants for 1 hr of tactile contact within the first 2 hr of birth and were allowed 15 extra hr of contact over the next 3 days. In contrast, mothers in the control group were allowed a short visit with their infants 6–12 hr after delivery for identification purposes and then time only to spend with their infants during feeding every 4 hr.

The investigators identified a number of differences between the two groups (Kennell et al., 1974; Klaus et al., 1972). When their infants were 1 month of age, mothers in the experimental group, compared with those in the control group, reported picking up their crying babies more and were more soothing to them, reported not wanting to leave the baby, and stood and viewed their infants more during a physical exam. When the infants were 1 year of age, mothers in the experimental group reported missing their infants more when they went to work, scored higher on the Bayley (1993) developmental test—a measure of physical and mental development—and again soothed their crying babies more and stood to view them more during a physical exam as compared with mothers in the control group. After investigators conducted these initial studies, other research quickly followed that supported the hypothesis that initial physical contact was necessary for bonding to occur and that the effects were enduring (De Chateau & Wiberg, 1977; Grossman et al., 1981; Hales, Lozoff, Sosa, & Kennell, 1977; Kennell & Klaus, 1979; Kennell, Trause, & Klaus, 1975; Kontos, 1978; Ringler et al., 1975; Ringler et al., 1978; Seashore, Leifer, Barnett, & Leiderman, 1973). Results similar to these were also found with father-infant dyads (Bowen & Miller, 1980; Keller, Hilderbrandt, & Richards, 1985; Rodholm, 1981).

Klaus and Kennell's (1981) original findings went unchallenged for roughly a decade, during which some 150 articles were published in pediatric journals and books; 38 studies were empirically based, whereas the remaining articles focused on the applications and implementations of bonding (Eyer, 1992). Hospital practices were changed to accommodate mother-infant bonding; mothers were given their babies immediately after birth and frequently over the course of the first few days, rather than being taken away and separated from their mothers for much of their hospital stay.

A second wave of research on bonding indicated that the previous studies may not have been as valid as once thought. Researchers criticized the bonding studies: the methodology, the strength of the presented data, and the validity of the measures employed (Myers, 1984). In one representative study, researchers compared 15 mothers who had 1 hr of touch at delivery and extended contact during breastfeeding with 15 mothers who received the usual hospital routine (i.e., infants were removed from mother soon after birth). There were no differences between the two groups of mothers when researchers measured 28 discrete responses (e.g., rocking, hugging, kissing, gazing [Svejda, Campos, & Emde, 1980]).

Researchers have conducted several reviews that critically evaluate the data on bonding (Goldberg, 1983; Klaus & Kennell, 1981; Lamb, 1982; Myers, 1984). The general consensus is that skin-to-skin contact, especially when allowed just after labor, may have beneficial effects on bonding, but only in the short term, not in the long term (Goldberg; Lamb). Thus, touch following birth likely enhances infant bonding, but it is not solely responsible for it, as once thought.

Summary and Conclusions

We have reviewed research indicating that touch plays a central role in the emotional lives of infants. Because visual acuity is limited in the early months of infancy (Salapatek & Banks, 1977), touch (like the voice) plays a prominent role in the communication of emotion. Touch communicates and generates both positive and negative emotions as well as plays a central role in attachment processes. From our review of the literature, we suggest that postnatal touch enhances infant bonding, but is not sufficient for its development.

A number of very important gaps remain in the literature concerning the effects of touch in infancy. First, there is a need for studies that use microanalytic methods to investigate how parents touch their children over the first years of life. Studying small numbers of children with repeated observations would illuminate how parents use touch to communicate and interact with their children. In addition, such methods would allow researchers to study the relationships between tactile behavior and other modalities of communication. The second gap in the literature deserving attention is how infants and children touch others. The vast majority of studies in the literature focus solely on how adults touch infants (for an exception, see Landau, 1989). Because tactile communication is bidirection-

al, the other side of the directional arrow deserves attention. Third, little is known about the effects of touch on children (although, see Weiss, 1990); we know little about touch in this stage of life compared with infancy and adulthood. Finally, the effects of touch on learning and cognition in early life warrant consideration. Although there is literature that examines the consequences of touch on learning and cognition (e.g., Weiss), the research is scant and unsystematic. Most research, instead, focuses on the neglect of touch, rather than how variants of normal touch influence learning and cognition.

Touch in Adulthood

Although the frequency of touch wanes after infancy, it continues to play a vital role in adulthood (Burgoon et al., 1996). Touch is ubiquitous around the world, and all cultures share a common understanding of the basic meanings of touch because it plays a key role in fundamental human exchanges such as aggression, comfort, and attachment. In this section, we focus on three major domains in which touch plays a fundamental role in adult life: compliance, power relations, and affective phenomena, which include the role of touch in intimacy, hedonic perception, and liking.

A rich empirical and theoretical foundation underlies the role of touch in adulthood. In fact, researchers proposed two functionalist approaches to the study of touch (Heslin & Alper, 1983; Jones & Yarbrough, 1985). We draw upon these orientations, but do not discuss some of the specific functions these researchers proposed because our goal here is to focus on touch that is not ritualistic (e.g., the handshake) or instrumental in nature (e.g., touching someone to show that person how to shoot pool). In addition, we do not focus on therapeutic touch, the blind, or touch in clinical contexts to provide continuity between the three major literatures discussed in the current article.

Approaches to the Study of Touch in Adulthood

Before embarking on some of the major functions that touch serves, it is appropriate to briefly describe the variety of methods and research designs that researchers have used to study touch in adulthood. Researchers have adopted three general approaches to the study of tactile communication, each with their own advantages and drawbacks: self-report, observational, and experimental methods (Thayer, 1986).

The self-report method provides an efficient and cost-effective means by which researchers investigate touch that transpires both in public and in private. Investigators who study touch using this method sometimes ask participants about their past tactile experiences (e.g., Jourard, 1966), whereas others ask participants to record their touch experiences just after they occur (e.g., Jones & Yarbrough, 1985; Willis & Rinck, 1983). Of course, the former method of self-

report assumes that participants' accurately recall their tactile experiences, which may not always be the case.

In a seminal study, typical of the latter self-report method, Jones and Yarbrough (1985) asked students in several psychology classes to record their tactile experiences online. Using this method, the participants notated their tactile experiences immediately following each time they touched someone or were touched by someone else. Of the touches recorded, 1,069 consisted of individual touches, and 139 consisted of touch sequences (i.e., a series of touches contained in one interaction). Jones and Yarbrough's study yielded some of the most fruitful and important data in the field of tactile communication. They derived several distinct meanings of touch including, but not limited to, support, appreciation, inclusion, sexual interest, affection, playful touch, compliance, and attention getting. Moreover, they were able to accurately gauge the frequency with which different types and qualities of touch occur in participants' lives. Although the external validity of Jones and Yarbrough's study is limited, given that most participants were college students in their early 20s, the study constitutes a major contribution to the study of tactile communication.

Researchers have also employed observational methods to study tactile communication (e.g., Blurton Jones, 1972; Hall, 1996; Willis & Dodds, 1998; Willis, Rinck, & Dean, 1978). Hall conducted an exemplary study using the observational method in which she unobtrusively recorded instances of interpersonal touch (quality, location, function, and duration), participants' gender, age, and status (student vs. member, prestige of one's institution and department) at three professional academic conferences. Hall found that although status did not mediate touch initiation (i.e., high-status individuals were no more likely to initiate touch than were low-status individuals), status did mediate the quality of touch that was used. Specifically, lower-status individuals initiated more formalized touch such as handshakes, whereas high-status individuals were more likely to initiate discrete touches to the arm and shoulders that were sometimes affectionate. We shall return to this study when we discuss touch and status relations.

Observational methods have some significant advantages over self-report and experimental studies. With well-trained, reliable, and unobtrusive coders, recordings of touch can be accurate and participant bias is reduced because the coder is not also the participant. Moreover, observational studies benefit from increased ecological validity that can only come when one observes real behavior in a real setting.

There are also some significant drawbacks to observational methods. First, there is no control over the variables of interest, so that inferences of causation are often more constrained than in experimental studies. Second, in many contexts, touch is not a frequent and spontaneous behavior; thus, observing natural tactile interactions can be very time and resource intensive compared with self-report and experimental methods. Finally, touch that transpires in personal contexts, such as the home, is difficult if not impossible to investigate. Observation-

al methods are typically best suited for studying touch in public spaces, where coders can be unobtrusive.

Finally, researchers have used experimental research designs to study the impact of touch on a variety of phenomena including compliance, power, and the communication of emotion (e.g., Crusco & Wetzel, 1984; Fisher, Rytting, & Heslin, 1976; Willis & Hamm, 1980). The experimental approach is typified by a study in which researchers investigated the effect of touch on compliance (Smith, Gier, & Willis, 1982). An experimenter approached participants in a supermarket and requested that they sample a new food item. Participants who were touched were more likely to taste and purchase the food compared with participants who were not touched. Other studies have used participants to judge encounters between people in which touch has been manipulated to see how the manipulations influence participants' judgments of the people shown or their relationship (e.g., Burgoon & Walther, 1990).

The experimental research design has the distinct advantage of being able to draw causal inferences about the effects of touch on a wide variety of phenomena compared with other methods. However, there are some significant drawbacks to most experimental studies of touch. Perhaps the most serious drawback has only recently been empirically identified (Lewis, Derlega, Shankar, Cochard, & Finkel, 1997). Lewis et al. instructed confederates to maintain constant nonverbal behavior while they either touched or did not touch participants on the elbow or forearm (i.e., manipulate tactile behavior only, not other nonverbal cues). Lewis et al. found that participants who were touched reported greater perceived social support than did participants who were not touched. However, when coding the confederates' nonverbal behaviors, the experimenters found that confederates who touched systematically displayed fewer expressive hand gestures and more nervous gestures, suggesting the possibility that the greater social support reported by participants who were touched was mediated by nonverbal cues other than touch.

We have described the variety of methods and research designs that have been employed to study touch in adulthood. Now, we focus on three major domains in which touch plays a fundamental role in adult life: compliance, power relations, and affective phenomena, which include the role of touch in intimacy, hedonic perception, and liking.

The Role of Touch in Compliance

The power of touch to increase the compliance of others is one of the most studied phenomena in the field of tactile communication (Brockner, Pressman, Cabitt, & Moran, 1982; Crusco & Wetzel, 1984; Foehl & Goldman, 1983; Goldman & Fordyce, 1983; Goldman, Kiyohara, & Pfannensteil, 1985; Gueguen, 2002a, 2002b, 2002c, 2004; Gueguen & Fischer-Lokou, 2002, 2003; Hornik, 1991; Hornik & Ellis, 1988; Kaufman & Mahoney, 1999; Kleinke, 1977; Nannberg &

Hansen, 1994; Patterson, Powell, & Lenihan, 1986; Paulsell & Goldman, 1984; Powell, Meil, Patterson, & Chouinard, 1994; Smith et al., 1982; Stephen & Zweigenhaft, 1986; Willis & Hamm, 1980). In one of the first studies to investigate the effect of touch on compliance, Kleinke found that participants were more willing to return a lost dime in a phone booth to a confederate who touched them (51%) compared with participants who were not touched (29%). Although critics have criticized Kleinke's seminal study because the touched participants were approached at a closer distance (1.5 feet) compared with nontouched participants (3 feet), his study provided the stepping stone for future investigations.

The effects of touch on compliance go beyond returning money; people will give more money if they are touched. Crusco and Wetzel (1984) conducted a study in which waitresses touched restaurant customers while returning their change. They assigned customers to one of three conditions: (a) those who were touched by the waitress twice on the palm, (b) those who were touched on the shoulder, and (c) those who were not touched. Crusco and Wetzel found that both types of touch increased the amount of tips and that both touch conditions were statistically equal in effect. These results were not influenced by gender, weather, day of the week, or the number in the dining parties.

Other researchers have investigated how touch influences people to comply with other types of requests. For example, Willis and Hamm (1980) conducted two experiments in which they touched half of the participants on the upper arm and did not touch the other half of the participants, holding constant other nonverbal cues. In the first study, a confederate asked participants to sign a petition for a local issue of concern, and in the second study, participants were asked to fill out a questionnaire. In the first study, 81% of the touched participants signed the petition compared with 55% of the participants in the control group; likewise, 70% of the touched participants in the second study completed the questionnaire, whereas only 40% of the participants who were not touched did so.

Researchers also investigated the role of touch in relation to the foot-in-the-door phenomenon in which a small request is asked of people in preparation for a more substantial request (Goldman et al., 1985; Patterson et al., 1986). Patterson et al. invited participants to the laboratory to fill out several questionnaires. After completing the measures, they asked subjects to stay longer and score some of the measures that were filled out previously by other participants. Half of the participants were touched on the shoulder during the request and the others were not. The former group spent significantly more time scoring inventories compared with the latter group.

Gender effects are pervasive in studies of compliance, but they are unsystematic and thus militate against simplistic generalizations and conclusions (Brockner et al., 1982; Hornik & Ellis, 1988; Patterson et al., 1986; Paulsell & Goldman, 1984; Powell et al., 1994; Stephen & Zweigenhaft, 1986). Some studies, for example, indicate that the targets of touch help more when female confederates touch them (e.g., Hornik & Ellis; Paulsell & Goldman), whereas other

studies indicate that targets help more when a confederate of the opposite sex touches them (e.g., Brockner et al.). However, it should be noted that several studies do not show gender effects (Crusco & Wetzel, 1984; Gueguen, 2002b; Gueguen & Fischer-Lokou, 2002, 2003; Nannberg & Hansen, 1994; Smith et al., 1982; Willis & Hamm, 1980). Thus, gender effects may be evident with some compliance outcome variables, but not with others. More systematic investigation is warranted to better understand gender's role in mediating compliance.

Overall, the literature is clear: Touch encourages compliance in interpersonal interactions. In addition to those previously cited, touch influences other compliance outcomes including helping others in need, increasing alcohol consumption (Kaufman & Mahoney, 1999), tending a stranger's dog for several minutes (Gueguen & Fischer-Lokou, 2002), increasing time and money spent shopping (Hornik, 1991), and increasing the sampling and purchasing of food (Smith et al., 1982).

Although there is clear evidence indicating that touch affects compliance, only a few studies have been conducted on the mechanisms that mediate the link between touch and compliance. Although one may hypothesize that attraction toward the toucher from the target may mediate the link, Patterson et al. (1986) found no such correlation. In addition, another study indicated that whether or not the targets noticed that they were touched made no difference in compliance rates (Gueguen, 2002c). Thus, two mechanisms may be able to be ruled out, which account for the touch-compliance link, but others remain including the status or power of the toucher.

Touch, Power, and Status

Henley (1973, 1977) proposed that touch is often used to communicate power and status to others. She proposed that individuals with higher status have the privilege to touch others to display their status advantage that lower-status people lack. This hypothesis resonates well with contemporary theories of power, indicating that power activates approach-related tendencies because it is associated with rewards and freedom, whereas lack of power activates inhibition-related behavioral tendencies because of its association with threat, punishment, and social constraint (Keltner, Gruenfeld, & Anderson, 2003). A recent meta-analysis, investigating several types of nonverbal behavior, showed that the type of touch may moderate the relation of touch to power and status (Hall, Coats, & Smith LeBeau, 2005).

In a landmark study, Henley (1973) provided empirical support for her hypothesis by having a male research assistant record 101 incidents of touch between people under 30 years of age in a variety of natural settings in a major city. Supporting her contention that touch communicates status, she found that touch was more frequently initiated by (a) people of higher socioeconomic status (SES) compared with lower SES, (b) older people compared with younger people, and

(c) males compared with females. Unfortunately, researchers have not attempted to replicate Henley's finding on SES, but have provided support, indicating that older people are more likely to initiate touch with younger people (Major, Schmidlin, & Williams, 1990; Stier & Hall, 1984).

The vast majority of research following Henley (1973) involving the initiation of touch has focused on potential gender asymmetries. As previously mentioned, Henley (1977) proposed that touch is used by higher-status people to communicate and maintain their relative position to lower-status individuals. Following this logic, she proposed that because men possess greater overall status in our society, touch in cross-sex interactions would be initiated more often by men than by women. A number of studies have been conducted to test Henley's prediction, but they have yielded mixed results with some empirical investigations finding gender asymmetries in the predicted direction (Grusky, Bonacich, & Peyrot, 1984; Major et al., 1990; Willis & Briggs, 1992) and other studies not (Hall & Friedman, 1999; Hall & Veccia, 1990; Jones, 1986; Willis & Rinck, 1983).

Investigators have conducted two major literature reviews that focus on gender differences in touch patterns (Major, 1981; Stier & Hall, 1984). In both, the authors concurred that, in general, empirical investigations support the view that people who initiate touch are perceived by others as more powerful and of higher status than those who do not (e.g., Summerhayes & Suchner, 1978). Moreover, the authors concured that self-report studies of touch frequency support Henley's (1973, 1977) gender asymmetry hypothesis. In contrast, Stier and Hall's and Major's conclusions regarding observational studies of gender differences of touch diverged significantly. Stier and Hall concluded, in general, that little empirical data exist to support Henley's (1977) hypothesis that men initiate touch more often in cross-sex dyads than do women, whereas Major came to the opposite conclusion; men are more likely than women to initiate touch in cross-sex interactions.

Major et al. (1990) discussed four mediating factors that may reconcile the divergent conclusions of the authors: (a) the age of the participants, (b) the relationship between toucher and recipient, (c) the setting in which tactile interactions occur, and (d) the intentionality of the touch. Below, we organize our discussion according to these factors.

Age of participants. There is a consensus that a gender asymmetry favoring men for touch exists among younger cross-sex dyads, but not older cross-sex dyads (Hall, 1996; Major et al., 1990). A number of empirical studies, some of which researchers conducted subsequent to the reviews previously mentioned, consistently support this conclusion (Guerrero & Andersen, 1994; Hall & Veccia, 1990; Willis & Briggs, 1992; Willis & Dodds, 1998). In a comprehensive and well designed investigation, Hall and Veccia observed 4,500 dyads that focused on their tactile interactions. Overall, there was no gender asymmetry in touch behavior, but when age was taken into account, a statistically significant sex difference

emerged; for dyads under 30 years of age, male-initiated touch dominated, but for dyads 30 years of age and over, female-initiated touch prevailed. Overall, these data partially replicate Henley's (1973) original data, indicating a gender asymmetry favoring men among dyads younger than 30 years of age.

Other data provide converging evidence of a general age effect for gender asymmetry and point to a mediating variable that may explain the age effect: the stage in which a couple is in their relationship (Guerrero & Andersen, 1994; Willis & Briggs, 1992). In one study, 696 cross-sex dyads were observed in public locations in seven Midwestern states (Willis & Briggs). Among dyads who were dating, engaged, or married less than 1 year, men initiated touch more often than did women, whereas among couples who were married a year or longer, women initiated touch more often than men.

Relationship between toucher and recipient. Major et al. (1990) posit that gender asymmetry for touch initiation favoring men is more likely between strangers or casual acquaintances compared with dyads composed of family members or friends. In the former dyad type, a gender asymmetry may exist because of the inherent status difference between men and women, whereas touch between family members or friends may more often communicate intimacy and positive emotions (Major et al.). Although there are no data to directly test their hypothesis, Major et al.'s evidence indicated that a gender asymmetry exists most strongly in cross-sex dyads composed of nonintimates.

The previously described studies regarding the impact of relationship stage on gender asymmetry of touch are also relevant to relationship type as a mediating variable (Guerrero & Andersen, 1994; Willis & Briggs, 1992). Within romantic couples, the type or stage of relationship affects the gender that initiates touch, with couples in the early stages of courtship and marriage demonstrating gender asymmetry favoring men, and established marriages demonstrating gender asymmetry favoring women. Although longitudinal data are clearly needed to disentangle relationship stage from cohort differences, the data indicate that the relationship between toucher and recipient mediates the gender of the touch initiator.

Setting in which the tactile interaction occurred. Henley (1973) observed tactile interactions in public nonintimate settings, where she found clear evidence that men initiated touch more often than did women in cross-sex dyads. Subsequently, Major et al. (1990) conducted a large-scale investigation using the same general procedure as did Henley, but they coded more tactile interactions in an effort to clarify the role of setting as a mediating variable of gender initiation of touch. The researchers observed almost 800 instances of touch between dyads in a small midwestern city and a large industrialized eastern city. Major et al. focused on three different types of settings in which to observe tactile interactions: (a) public, nonintimate settings (e.g., stores, shopping malls, downtown business districts, and a college campus); (b) recreational settings (e.g., outdoor parks and beaches,

art galleries, and a bar); and (c) greeting or leave-taking settings (e.g., airports and bus stations). As hypothesized, men initiated contact more often than did women in cross-sex dyads in public, nonintimate settings, whereas the gender asymmetry disappeared in greeting or leave-taking settings and was mitigated in recreational settings. Such results lend credible support to the conceptual use of setting as a mediating variable in the gender asymmetry of touch initiation.

Intentionality of the touch. Some investigators who are interested in potential gender asymmetries of touch code touches that are solely intentional in nature (e.g., Dibiase & Gunnoe, 2004; Hall, 1996; Henley, 1973; Major, 1981; Major et al., 1990; Willis & Briggs, 1992), whereas others code all types of touch, even those that are accidental (e.g., Beier & Sternberg, 1977; Smith, Willis, & Gier, 1980). Major et al. pointed out that intentional touch with the hand, rather than inadvertent touch, is more likely to communicate status and power. This notion follows from the premise that touch is a status privilege and, as such, people of higher status have the choice to touch others, whereas those of lower status do not. A recent cross-cultural study partially supported Major et al.'s observation (Dibiase & Gunnoe). In the study, Dibiase and Gunnoe observed people touching each other in Italy, the United States, and the Czech Republic, a country the authors of the study claim has very traditional gender roles. Researchers coded both hand and nonhand touches. Overall, men initiated touch with their hand more often than did women, although this effect was most apparent in the Czech Republic, where traditional gender roles are strongest. As for nonhand touch, women in Italy and the Czech Republic initiated touch more often than did men, but there was no difference among men and women in the United States. Overall, the preponderance of evidence strongly indicates that intentional touch, compared with unintentional touch, results in a gender asymmetry that favors male touch initiation in cross-sex dyads (when mediated by the variables previously discussed; Hall & Veccia, 1990; Major; Major et al.; Willis & Briggs, 1992).

To summarize, the data indicate that there is a significant gender asymmetry favoring men in cross-sex dyads when the dyads (a) are young, (b) are in the early stages of a romantic relationship or are casual acquaintances, (c) are touching in public, nonintimate settings, and (d) are touching in an intentional manner with the hand. It is interesting to note that these conditions are similar to those of Henley's (1973) original study.

Limitations. There are a number of conceptual and empirical problems with the literature on touch and status. The first problem lies in the inherent complexity that surrounds the concepts of power and status (e.g., Burgoon & Dillman, 1995; Edinger & Patterson, 1983; Hall, 1996); researchers use varying operational definitions of these concepts, which make comparisons between studies difficult.

A second problem is conflating gender with status. They are not isomorphic constructs; being a particular gender may not necessarily elevate one's status. A

few studies have indexed status by means other than gender (Goldstein & Jeffords, 1981; Hall; Juni & Brannon, 1981). As mentioned, Hall conducted a clever study in which observers coded tactile interactions at three professional academic meetings. Then, she examined touch initiation in relation to participants' gender and relative status (computed using variables such as prestige of institutional affiliation and PhD-granting institution, membership status, reputation of department, and number of publications). Although she did not find a gender asymmetry for cross-sex touch initiation, she did find that higher-status people touched lower-status people differently than vice versa; higher-status people initiated touch that was more affectionate (e.g., arm around the shoulder), whereas lower-status people initiated more formal touches (e.g., handshakes).

Another illuminating finding out of Hall's (1996) study was that when status was held constant in analyses of cross-sex dyads, men initiated touch more often than did women, supporting Henley's (1977) gender hypothesis. Drawing upon expectation states theory (Berger, Rosenholtz, & Zelditch, 1980), Hall suggested that when task- or situation-relevant status cues are not present, gender may be used to infer status. This explanation may help explain some of the general inconsistencies in this literature. Clearly, more studies like Hall's, which correlate status (indexed using a variety of means) with touch initiation (both quantity and quality of touch) would be helpful.

A third problem is the lack of converging research operations used to investigate status and touch. To our knowledge, no cross-cultural studies of touch have been designed to specifically test Henley's (1973, 1977) hypothesis. The cross-cultural studies thus far have tended to focus on gross frequencies of touch without attention to any of the mediating variables such as age and setting. Would the findings on gender asymmetry of touch initiation hold in countries different than the United States? Are there ways of operationalizing status in other countries that are not possible in the United States that would provide unique tests of Henley's hypothesis?

An additional means by which investigators could provide converging research operations is to conduct more experimental studies that manipulate status. Among the few researchers to conduct an experimental study were Juni and Brannon (1981), who manipulated the status of individuals by changing their dress attire. Other studies using experimental manipulations are needed to increase the confidence with which researchers can infer the causality between touch and status.

Touch and Affective Phenomena

Just as touch is central to the study of emotion in infancy it is also important in adulthood. Researchers have investigated touch and its relationship to affective phenomena in a number of different domains. We will focus on the three related, but distinct, domains of research that have received the most attention from researchers: (a) intimacy, (b) hedonic ratings, and (c) liking.

Intimacy. In a comprehensive literature review, Burgoon and Hale (1984) found that relational communication is characterized by at least 12 conceptually distinct themes. One of these themes—intimacy—was considered to be primary because it consistently appeared in almost all of the 11 different literatures evaluated. Touch constitutes one of the primary means of communicating and fostering intimacy, especially touch leading to sexual intimacy. The power of touch is well captured by Thayer (1986), who stated that "Touch is a signal in the communication process that, above all other communication channels, most directly and immediately escalates the balance of intimacy. . . . To let another touch us is to drop that final and most formidable barrier to intimacy" (p. 8). Touch is commonly cited as a fundamental immediacy behavior (Mehrabian, 1971; Patterson, Reidhead, Gooch, & Stopka, 1984) and plays an important role in major theories of intimacy, including equilibrium theory (Argyle & Dean, 1965), arousal theory, (Patterson, 1976), and discrepancy arousal theory (Cappella & Greene, 1982).

Of course, touch related to the communication of intimacy is not uncommon (Jones & Yarbrough, 1985; Jourard, 1966; Willis & Rinck, 1983). In one study, college participants recorded their tactile interactions with others using a personal log method (Willis & Rinck). Of the almost 1500 reported touches, the majority of tactile interactions took place in private settings (e.g., home, automobile), and most of these touches were of a personal nature. The researchers also classified sexual touches (e.g., hand to thigh, hand to buttock, hand to breast, hand to genitalia, mouth to breast, and genitalia to genitalia). A majority of the women and just over one third of the men reported at least one of these touches. Inferential caution must be noted regarding this study given its limited sample size and lack of male participants (n = 17).

In another study using a log method, Jones and Yarbrough (1985) identified three touch categories that nearly always fostered intimate experience: (a) touches expressing sexual intent and attraction, which involved holding or caressing (e.g., caressing on private body parts); (b) touches expressing positive affection and general positive regard toward the other; and, (c) touches communicating togetherness and usually involving lower body parts (e.g., knees touching). These types of touches occurred most often in close cross-sex relationships.

Morris (1971) identified a specific sequence of behaviors that is typically followed by heterosexual romantic couples to communicate intimacy. The first three include eye-to-body and eye-to-eye contact followed by voice-to-voice (i.e., small talk) communication. Interestingly, the following nine behaviors identified by Morris pertain to touch. In order, they include (a) hand-to-hand contact, (b) arm-to-shoulder contact, (c) arm-to-waist contact, (d) mouth-to-mouth contact, (e) hand-to-head contact, (f) hand-to-body contact, (g) mouth-to-breast contact, (h) hand-to-genitals contact, and finally, (i) genitals-to-genitals (or mouth-to-genitals) contact. Morris reported that the sequence is not strictly invariant because there is some variation in tactile patterns between couples. In addition,

some of the steps may be skipped because of canonical forms of tactile communication such as shaking hands, a goodnight kiss on a date, or dancing.

A number of researchers employing a variety of methods have found that the quantity of touch between couples is minimal in the initial stage of relationships, waxes thereafter reaching the quantitative apex during the intermediate stages of relationships (usually when monogamously dating or engaged), and wanes after the first year of marriage (Emmers & Dindia, 1995; Guerrero & Andersen, 1991; McDaniel & Andersen, 1998; Willis & Briggs, 1992). In one study, researchers recorded participants' tactile interactions, and then a female experimenter approached the participants and asked them to describe their relationship (Willis & Briggs). Couples who had been married longer than 1 year touched each other significantly less than couples who had been married for less than 1 year or who were engaged or dating. Evidence for this general pattern also comes from other observational studies (Guerrero & Andersen; McDaniel & Andersen). Overall, the literature indicates that high quantities of tactile interaction are needed to establish intimate relationships, and men tend to initiate tactile interactions more often early in relationships.

Data also indicate that the quantity and quality of touch observed between couples reflects the intimacy and happiness of their relationships (Beier & Sternberg, 1977; Heslin & Boss, 1980). Beier and Sternberg videotaped recently married couples while interviewing them about their adjustment to marriage, and coded self-touching and other-touching among other variables. It is interesting to note that couples who reported the greatest amount of marital happiness touched each other more and themselves less, as compared with couples reporting low marital happiness. In another study, researchers unobtrusively observed travelers at an airport for the type of tactile involvement that occurred between them and someone waiting for them at a terminal. There was a strong positive relationship between the self-reported intimacy of the relationship and the rated intimacy of touch used (Heslin & Boss). Taken together, these studies indicate that the quantity and quality of touch between couples reflect their relationship satisfaction and the degree to which they have an intimate relationship. Of course, these findings must be interpreted with caution given the correlational nature of the research designs.

A number of investigators have also been interested in what observers infer about intimacy from the tactile behavior in dyads' interactions (Burgoon, 1991; Burgoon, Buller, Hale, & DeTurck, 1984; Floyd & Voloudakis, 1999; Pisano, Wall, & Foster, 1986). In this tradition, researchers show participants a photo or a videotaped interaction and ask participants to rate how intimate the tactile interaction was or how intimate the relationship is on the basis of the touches observed in the interaction. For example, Burgoon showed participants photographs and varied the type of tactile interactions between the models. She found that handholding and face touching expressed the most intimacy compared with other types of touch. More recently, Floyd (1999) presented a videotaped interaction of

two actors embracing each other and manipulated the duration and form of the embraces. He found that both the form and the duration of the embraces influenced participants' perceptions of the intimacy of the tactile displays.

Overall, there is ample evidence indicating that touch communicates and fosters intimacy. However, there are some significant challenges to the study of touch and intimacy. Perhaps the most daunting problem faced by researchers is that the vast majority of touches that communicate intimacy are private. This is a challenge for researchers who wish to use methods other than self-report. The challenge for researchers in the future will be to construct more research methodologies that will allow them to observe couples in private and natural settings using video-recording devices. Another step for researchers is to investigate how touch is used to communicate intimacy in gay and lesbian couples. The study of gay and lesbian samples in relation to touch and intimacy would be a very fruitful domain of investigation. Finally, future studies may benefit from measuring the encoder's attitudes and perceptions of tactile displays of intimacy. Typically, researchers in this domain either ask the recipient of intimate touch or observers of the tactile interaction what they believe and think about the touch. Inquiring about the toucher's attitudes and motivations for touching may be very illuminating.

Hedonics of touch. For decades, researchers have been interested in the meaning that people ascribe to touch and how meaning is influenced by the identity of the toucher and recipient, as well as the context in which touch takes place. As mentioned in the introduction, the same touch can have very different hedonic consequences (the principle of equipotentiality); placing one's arms around one's best friend's shoulders will be perceived very differently than will touching a stranger in the same manner.

The perceived hedonic quality of different types of touch is moderated by type of relationship, gender, status, and context. In a series of studies designed to investigate the hedonic meaning that people ascribe to touch, Nguyen, Heslin, and Nguyen examined the effects of the gender of the communicators, their relationship, and the types and location of touch (Heslin, Nguyen, & Nguyen, 1983; M. L. Nguyen, Heslin, & Nguyen, 1976; T. D. Nguyen, Heslin, & Nguyen, 1975). In the first study, Nguyen et al. (1975) asked a college-aged sample to identify what it meant for them to be touched (e.g., patted, squeezed, brushed, stroked) by a close person of the opposite sex (excluding family) on 11 different areas of the body. Subjects identified the meaning they attributed to each touch by scales that represented degrees of pleasantness, sexual desire, playfulness, friendship or fellowship, and warmth or love. The most significant finding from this study was that, the more that women perceived touch as sexual, the less they perceived it as warm, loving, playful, or friendly ($r = -.80$), whereas the more men perceived touch as sexual, the more they perceived it as pleasant, warm, and playful ($r = .59$).

In a follow-up investigation, Nguyen et al. (1976) employed the same methodology, except they included a married and unmarried sample and added an additional response scale (invasion of privacy). Two noteworthy findings came out in this study. First, although all men found sexual touch to be pleasant, warm, and playful, the correlation was stronger for unmarried men than for married men. Second, married women perceived sexual touch as warm and as pleasant as unmarried men (r = .64), but unmarried women did not.

Nguyen, Heslin, and Nguyen (M. L. Nguyen et al., 1976; T. D. Nguyen et al., 1975) found that the type and location of touch influenced the meaning that participants attributed to them. Playful and friendly touches were characterized by squeezing and patting, whereas stroking was associated with warmth or love and sexual desire (some of these attributions were moderated by gender). In terms of location, playfulness was associated with touch on the leg, whereas sexual desire was associated with touch on the genital area. It is interesting to note that some meanings such as loving, playfulness, friendliness, and pleasantness were significantly correlated with each other, indicating that participants did not consistently differentiate between these positive affective phenomena.

Researchers conducted a third study to increase the scope of the previous two investigations by using the same methodology, but participants also were asked to consider touch from strangers and people of the same sex (Heslin et al., 1983). This allowed the researchers to better understand the variables that moderate the relationship between touch and how it is perceived. Participants rated touch from opposite sex friends, for both men and women, as less of an invasion of privacy and more pleasant than touch from same-sex friends or same-sex strangers. These differences were most dramatic for touches that were perceived as sexual. However, there was a stark gender difference; whereas women perceived touch from opposite-sex strangers to be unpleasant and an invasion of privacy, men did not. Rather, men perceived touch, even sexual touch, from an opposite-sex stranger to be as pleasant as from a close female friend. Thus, men find it pleasant to receive touch from women strangers, whereas women find touch pleasant only when it comes from close friends of the opposite sex. Both men and women rated sexual touches from opposite-sex friends to be the most pleasant, but women's second highest rating was for stroking nonsexual touches by a close male friend, whereas men's second highest rating was for stroking sexual touches by a female stranger.

Heslin and his colleagues point out three significant implications of their research (Heslin & Alper, 1983; Heslin et al., 1983). First, same-sex touch, especially sexual touch and touch from strangers, is often perceived as unpleasant and an invasion of privacy, a finding that has been replicated (e.g., Hewitt & Feltham, 1982; Willis & Rawdon, 1994). Other researchers have shown that disdain for same-sex touch is greater for men compared with women (e.g., Hewitt & Feltham; Willis & Rawdon) and the former's comparatively anxious perception of same-sex touch has been attributed to their fear of being perceived as homo-

sexual (Collier & DiCarlo, 1985; Heslin & Alper, 1983). Second, to be perceived positively, the intimacy of touch, at least for women, must be congruent with the intimacy of the relationship. Thus, sexual touch will only be perceived positively when it is presented by an intimate other. Finally, men and women weigh the familiarity of the person touching them with different importance; men tend not to mind being touched, sexually and otherwise, by female strangers, but women dislike touch from opposite-sex strangers. Future researchers should investigate gay men and lesbians to discover how their perceptions differ from heterosexuals' with regards to the perceived hedonics of touch.

Recently, Hertenstein, Keltner, App, Bulleit, and Jaskolka (2006) provided evidence that strangers in Spain and the United States could accurately decode distinct emotions when they were touched by another person, thereby challenging earlier views that conceptualized touch solely as a gross hedonic signaling system or an intensifier of other emotion-signaling systems. The researchers placed two strangers in a room where they were separated by a barrier. They could not see one another, but they could reach each other through a hole. One person touched the other on the forearm, each time trying to convey one of 12 emotions. After each touch, the touched person had to choose which emotion the encoder was trying to communicate.

The results indicated that participants decoded anger, fear, disgust, love, gratitude, and sympathy at above chance levels, whereas participants decoded happiness, surprise, sadness, embarrassment, envy, and pride at less than chance levels. Accuracy rates ranged from 48% to 83% for the accurately decoded emotions, which is comparable with those observed in studies of facial displays and vocal communication (Elfenbein & Ambady, 2002; Scherer, Johnstone, & Klasmeyer, 2003). In addition, specific tactile behaviors demonstrated by the United States sample were associated with each of the emotions. For example, sympathy was associated with stroking and patting, anger with hitting and squeezing, disgust with a pushing motion, gratitude with shaking of the hand, fear with trembling, and love with stroking.

Liking. We know from the literature previously discussed that touch is perceived pleasantly under some circumstances and is an invasion of privacy in others. However, does touch increase or decrease liking of the toucher? Researchers have designed a number of studies to address this question.

In one of the earliest studies to investigate the effect of touch on liking, a confederate library clerk momentarily touched men and women participants while handing back change (Fisher et al., 1976). Participants who were touched reported greater positive affective states and liked the library clerk more than did participants who were not touched (all other aspects of behavior between the experimental and control conditions were uniform). This effect was not influenced by the sex of the toucher or whether or not the participants realized they were being touched. However, there was nearly a significant Touch × Sex of Partici-

pant interaction ($p < .07$); women primarily carried the touch main effect, whereas men's ratings of the clerk were more variable.

Although the sex of the confederate did not affect participants' evaluations in Fisher et al.'s (1976) investigation, researchers have shown evidence of an effect. In one study, women and men confederates greeted participants arriving for a study in one of three ways: (a) a polite nod with no touch, (b) a simple handshake, or (c) a handshake with a gentle squeeze on the right upper arm. Overall, the greater the amount of touch the confederate used, the more that the participants liked the confederate. However, there were some gender differences. The more touch that was involved in the initial contact when a male touched a female, the more the woman perceived the man as an acceptable marriage partner. In contrast, the more touch that was involved in the initial contact when a womean touched a man, the less the man perceived the woman as an acceptable marriage partner (Silverthorne, Micklewright, O'Donnell, & Gibson, 1976).

Another study indicated that males respond less positively to touch than do women (Whitcher & Fisher, 1979). A woman nurse, who was a confederate, either touched (on the hand and arm) or did not touch patients who were awaiting elective surgery. Men who were touched reported experiencing more anxiety leading up to their surgery and had higher blood pressure (both systolic and diastolic) following surgery than did men who were not touched. Women who were touched, compared with those who were not, saw the nurse as more interested in them, were less anxious about their impending surgery, and had lower blood pressure (both systolic and diastolic) following the surgery. Again, women responded significantly more positively to touch than did men.

The studies that we have discussed thus far indicate that, when touched by strangers (in a nonsexual manner), women like touchers more, whereas men's reactions to being touched are negative or neutral, particularly if they are touched by women (Fisher et al., 1976; Major, 1981; Silverthorne et al., 1976; Sussman & Rosenfeld, 1978; Whitcher & Fisher, 1979). However, not all researchers have found that men react negatively or neutrally to touch (e.g., Burgoon, Walther, & Baesler, 1992; Hornik, 1992; Jourard & Friedman, 1970; Silverthorne, Noreen, Hunt, & Rota, 1972). For example, Jourard and Friedman found that both men and women participants reported more positive evaluations of a male interviewer after being touched by him. Major suggested that men and women are affected positively when touched by a high-status person, whereas men react negatively and women positively when touched by a lower-status person. More empirical studies are needed to adequately address Major's hypothesis.

Although there is ample empirical data indicating that touch increases liking, at least under some circumstances, this is not always the case. As Nguyen, Heslin, and Nguyen (Heslin et al., 1983; M. L. Nguyen et al., 1976; T. D. Nguyen et al., 1975) have shown, the gender and relationship of the touch initiator and recipient play an important role in how touch is perceived. In addition, Andersen and Sull (1985) showed that some people are *touch avoidant,* meaning that they

feel discomfort and experience anxiety when being touched. Thus, personality factors also play a role in determining the hedonic value of touch beyond relational factors (e.g., relationship status).

Researchers have identified several functions as being served by touch other than those previously discussed. For example, studies indicate that touch (a) increases the likelihood that a recipient will talk more (Aguilera, 1967), (b) gains people's attention in preparation for a conversation (Andersen, 1985; Mehrabian, 1971), (c) signals the initiation and termination of interaction (Axtell, 1999), and (d) heals certain ailments (Field, 2001). Undoubtedly, researchers will better understand the functions served by touch if more attention is given to this modality of communication.

Summary and Conclusions

Touch plays a fundamental and important role in human interaction, which includes the gaining of compliance, the communication of status and power, intimacy, hedonics, and liking. The role of touch in adulthood has received more attention from researchers compared with the other domains in this review. Nevertheless, the modality of touch continues to be neglected when compared with the other sensory modalities used in nonverbal communication.

We have two general recommendations for future research in this area. First, many researchers have pointed out that there is a clear bias by researchers studying touch to focus on its positive effects in human interaction (e.g., Major, 1981). This is somewhat ironic given that other domains of nonverbal communication, particularly the field of affective science, have been dominated by studies focusing on negative affect (Snyder & Lopez, 2002). Although studying the role of touch in negative types of interaction (e.g., aggression) goes against the current zeitgeist of the positive psychology movement, our knowledge of the full spectrum of behavior in which touch is involved would be significantly enhanced.

Second, our knowledge would be extended if more studies expanded their samples in three ways. First, the study of touch would benefit from studying populations with varying sexual orientations. The vast majority of the investigations focus on gender as one of the main variables that moderates the effects of touch. Much could be learned by studying people with varying sexual orientations to not only better understand this population by itself, but to also provide comparison data for heterosexual orientations (Floyd, 2000; Roese, Olson, Borenstein, & Martin, 1992). Second, our knowledge of touch would be expanded if other cultures were studied with the same methodological sophistication that has been employed with samples in the United States. Like most areas of psychology and communication, researchers employ samples of convenience. As a result, U.S. samples are investigated in the vast majority of the studies. Researching other cultures would significantly enhance our understanding of touch (cf., Dibiase & Gunnoe, 2004). Finally, the age of the participants in most samples is restricted

to young adults, again because researchers use samples of convenience. Investigators typically conduct field studies in outdoor settings and conduct experimental and self-report studies in university settings. All of these settings tend to disproportionately represent young people, and researchers would benefit from studying middle-aged and older adults. Although we chose not to review studies in therapy and medical settings, researchers conducting studies in these contexts have been more successful at gaining access to these populations.

TOUCH IN NONHUMAN PRIMATES

Although examining the communicative functions of touch in nonhuman primates is important in its own right, doing so also allows us to begin to see possible phylogenetic continuities between humans and nonhuman primates. Touch plays an important role in the physical, emotional, and social development of nonhuman primates. The role of touch in nonhuman primates has been studied with emphasis placed on attachment in the mother-infant relationship, touch in postconflict events, and touch as a social mechanism. The literature can be divided broadly into five domains in which touch plays a significant role: (a) relationships between touch and status, (b) touch in response to stress, (c) touch during reconciliative acts, (d) touch related to sexual relations, and (e) touch in attachment. The aim of this section is to synthesize the literature across a variety of contexts and species that have been studied, although reference to species differences will be made when appropriate. Table 2 presents the empirical investigations cited in the present section. Before embarking on a discussion of how touch functions for nonhuman primates, we discuss the evolutionary importance of touch.

Evolutionary Importance of Touch

The evolutionary origins of grooming may have been to remove parasites, ticks, and lice that are common in natural environments (Hutchins & Barash, 1976; Sparks, 1967).[6] Nonhuman primates may engage in social-grooming, self-grooming, or both to remove lice, parasites, and other objects (Tanaka & Takefushi, 1993). *Social grooming*, also known as allogrooming, may have developed in nonhuman primates to groom each other in places they could not reach themselves. The groomers focus on areas of the body (e.g., the back, neck, and anal region) that the recipients cannot reach by themselves (Hutchins & Barash; McKenna, 1978; Sparks).

Despite the necessity of grooming to protect nonhuman primates from disease, most researchers agree that the prevalence of grooming in species is indicative of important social functions (Boccia, 1983, 1989; Boccia, Rockwood, & Novak, 1982; Dunbar, 1991; Harlow, Harlow, & Hansen, 1963; McKenna, 1978; Oki & Maeda, 1973; Sparks, 1967). Support for this assertion comes

TABLE 2. Studies of Tactile Communication in Nonhuman Primates Classified According to Methodology, Subjects, and Examined Variables

Author	Study type	Subjects	Variable
Aureli (1992)	Observational	39–50 *Macaca fascicularis*	Reconciliatory behavior
Aureli et al. (1999)	Observational/ physiology	2 adult female *Macaca mulatta*	Social behaviors—heart rate response to social interactions
Aureli et al. (1989)	Observational	1 adult male, 9 adult female, 5 subadult male, 4 juvenile male, 3 juvenile female, and 7 infant *Macaca fascicularis*	Reconciliatory behavior and tension reduction
Barton (1983)	Observational	Primate groups at Jersey Wildlife Preservation Trust	Physical aspects of grooming
Bernstein et al. (1983)	Observational	14 male and 8–10 female *Macaca mulatta*, 9 male and 8 female *Macaca arctoides*, 8–11 male and 8–10 female *Macaca nemestrina*, 8 male and 8 female *Macaca nigra*, 10 male and 7–8 female *Cercocebus atys*	Social behavior and aggression
Blurton Jones & Trollope (1968)	Observational	*Macaca arctoides*	Social behaviors
Boccia (1983)	Observational	2 male and 2 female *Macaca mulatto* from 2 groups	Social grooming in comparison to self-grooming
Boccia (1989)	Observational	*Macaca nemestrina* (1 male, 5 females, and several infants) and *M. radiata* (1 male, 8 females, and several infants/ juveniles)	Grooming and comparison between species
Boccia et al. (1989)	Observational	Adult female *Macaca nemestrina*	Physiology of grooming
Boccia et al. (1982)	Observational	2 male and 2 female *Macaca mulatto* from 2 groups	Grooming and influence of social context and behavior

(table continues)

TABLE 2. ***Continued***

Author	Study type	Subjects	Variable
Borries et al. (1994)	Observational	11–13 female *Presbytis entellus entellus*	Grooming and the social network
Bowman et al. (1978)	Experimental	4 male and 4 female talapoins in captivity	Effects of female estrogen and dominance on male sexual attention
Buirski et al. (1973)	Observational	4 male and 3 female *Papio anubis*	Social behaviors and dominance
Butovskaya et al. (1994)	Observational	1 male and 18 female *Macaca arctoides*	Allogrooming
Cheney (1977)	Observational	24–30 *Papio cynocephalus ursinus* (2 adult males and 8 adult females specifically)	Agonistic interaction in adults and juveniles
Cheney (1992)	Observational	Adult female *Cercopithecus aethiops* in the wild and in captivity	Grooming distributions in females
Ceo et al. (1978)	Observational	3 female and 1 male infant, their mothers, and one "aunt" *Siamiri scureus*	Mother-infant relationship and adrenal response to separation
Cords (1993)	Experimental	2 male and 18 female *Macaca fascicularis*, in 10 dyads	Qualifications of reconciliatory behavior
D'Amato et al. (1982)	Observational	8 male, 18 female, and 5 infant *Macaca fuscata fuscata*	Grooming and influences of mating season
Das et al. (1998)	Observational	4 male, 15 female, and juvenile/infant *Macaca fascicularis* in captivity	Reconciliatory behavior and stress reduction
Defler (1978)	Observational	43–57 *Macaca radiata* and 33–35 *Macaca nemestrina* in captivity	Grooming and comparison between species
Drickamer (1976)	Observational	214 *Macaca mulatta*	Grooming behavior of troups
Dunbar (1991)	Observational	44 species of free-living primates	Social functions of grooming
Gunnar et al. (1981)	Experimental	7 male and 2 female infant *Macaca mulatta* and their mothers	Mother-infant attachment and pituitary and adrenal responses to separation

(table continues)

TABLE 2. ***Continued***

Author	Study type	Subjects	Variable
Gust & Gordon (1993)	Observational	4 groups of *Cerocebus torquatus atys* (primary group of 8 adult males, 37 adult females, and 40 immature animals)	Reconciliatory and agonistic postconflict behavior
Harcourt (1979)	Observational	2 groups of *Gorilla gorilla beringei*–each with one silverback male, one blackback male, and adult females	Social relationships between adult males and females
Harlow (1958)	Experimental	*Macaca mulatta* infants	Infant attachment and contact comfort
Harlow & Harlow (1962)	Experimental	*Macaca mulatta* infants	Infant attachment and social deprivation
Harlow & Harlow (1969)	Experimental	*Macaca mulatta* infants	Infant responses to different levels of social or maternal isolation
Harlow et al. (1963)	Experimental	*Macaca mulatta* infants	Affectional systems in infants
Harlow & Suomi (1970)	Experimental	*Macaca mulatta* infants	Infant attachment and contact comfort
Hinde (1976)	Experimental	*Macaca mulatta*	Infant attachment and differing consequences of separation depending on situation
Izawa (1980)	Observational	9 male and 7 female *Cebus apella* in the wild	Social behavior including rank, grooming, eating behavior, and resting
Jensen (1965)	Experimental	5 female *Macaca nemestring* and their infants (2 males and 3 females)	Mother-infant attachment and responses to separation
Jensen & Tolman (1962)	Experimental	2 male infant *Macaca nemestrina* and their mothers	Mother-infant attachment and effects of separation
Kaplan (1978)	Observational	39 male and 48 female free-ranging *Macaca mulatta*	Aggression and the role interference plays in maintaining the group structure
Koyama (1973)	Experimental/ observational	23 *Macaca radiata*	Social relationships: selection of partners in grooming and dominance

(table continues)

TABLE 2. ***Continued***

Author	Study type	Subjects	Variable
Kraemer et al. (1989)	Experimental	18 male infant and 12 adult female *Macaca mulatta*	Mother-infant attachment and effect of cerebrospinal fluid norepinephrine and biogenic amine metabolites
Kutsukake & Castles (2001)	Observational	58 adult male, 98 adult female, 34 juvenile, and 37 infant *Macaca fuscata fuscata*	Reconciliatory behavior and postconflict stress
Levine & Stanton (1990)	Observational/ physiology	Mother-infant *Saimiri sciureus*	Mother-infant attachment in relation to pituitary-adrenal response and reduction of arousal
Lindburg (1973)	Observational	9 male, 19 female, 15 juvenile male, 7 juvenile females, and 18 infant *Macaca mulatta*	Grooming in relationship to social interactions
Maestripieri & Wallen (1997)	Observational	32 male, 46 female, and 25 young *Macaca mulatta*	Social relationships and gestural communication
Matheson (1999)	Observational	28 female *Macaca mulatta* in a natural group	Reconciliatory behavior and consolation
McKenna (1978)	Observational	1 adult male, 8 adult female, 4 immature female, 4 immature male, and 2 infant female *Presbytis entellus*	Social functions of grooming
Mendoza et al. (1978)	Experimental	17 mother-infant *Saimiri sciureus* dyads and 12 surrogate reared infants	Mother-infant attachment and pituitary-adrenal response to separation
	Experimental	7 adult female *Saimiri sciureus*	Mother-infant attachment and pituitary-adrenal response to separation
Michael et al. (1978)	Experimental	8 adult male and 11 adult female *Macaca mulatta* in captivity	Social and sexual interactions as reinforcers of operant conditioning

(table continues)

TABLE 2. ***Continued***

Author	Study type	Subjects	Variable
Mitchell & Tokunaga. (1976)	Experimental	6 male and 6 female infant *Macaca mulatta* and their mothers, and 1 female adult and 1 male infant as stimulus	Mother-infant attachment and response to repeated separation
Nishida (1979)	Observational	17 female *Pan troglodytes* with 1–4 infants each	Development of social grooming in infants
O'Brien (1993)	Observational	15 adult female *Cebus olivaceus*	Social behavior and affiliative or allo-grooming
Oki & Maeda (1973)	Observational	Adult *Macaca fuscaca*	Social behavior and grooming patterns
Parr et al. (1997)	Observational	Females in 5 social groups of *Cebus apella*	Grooming in relation to status
Perry (1996)	Observational	4 adult male, 6 adult female, and 11 juvenile and infant *Cebus capucinus* in the wild	Social relations between females
Reite et al. (1989)	Experimental	3 male and 2 female infant *Macaca radiata*	Mother-infant attachment and responses to separation
Reite & Short (1978)	Experimental	5 male and 5 female infant *Macaca nemestrina*	Mother-infant attachment and sleeping patterns in separated infants
Reite et al. (1978)	Experimental	10 infant *Macaca nemestrina*	Mother-infant attachment and heart rate and body temperature after during separation
Ren et al. (1991)	Observational	2 male and 7 female *Rhinopithecus roxellanae roxellanae*	Reconciliatory behavior and agonistic encounters and later behavior
Rowell et al. (1991)	Observational	17 adult and juvenile female *Cercopithecus mitis stuhlmanni* in the wild	Social relations between females and grooming as a cohesive element
Sackett et al. (1973)	Experimental	8 male infant *Macaca mulatta*	Adrenocortical responses and behaviors of infants raised in different settings

(table continues)

TABLE 2. ***Continued***

Author	Study type	Subjects	Variable
Sade (1972)	Observational	16 male and female *Macaca mulatta* in the wild	Social relationships and dominance
Sambrook et al. (1995)	Observational	29 female *Papio cynocephalus anubis* in 2 groups of wild baboons	Female grooming in relation to status
Schino, Aureli, & Troisi (1988)	Observational	1 male and 5 female *Macaca fascicularis*; 5 male, 16 female, and 5 juvenile *Macaca fuscata*; and 1 male, 8 female, and 3 juvenile *Macaca nemestrina*	Grooming relationships
Schino et al. (1988)	Observational	2 male and 11 female adult *Macaca fascicularis*	Grooming and relationship to tension reduction and hygiene
Schino & Troisi (1992)	Experimental	10 juvenile macaques	Grooming and opioid levels involved
Schlottmann & Seay (1972)	Experimental	6 male and 6 female infant *Macaca irus* and their mothers	Mother-infant attachment and responses to separation
Seay et al. (1962)	Experimental	2 male and 2 female infant *Macaca mulatta* and their mothers	Mother-infant attachment and responses to separation
Seyfarth (1980)	Observational	11–14 adult male, 23 adult female, and 19–38 immature *Cercopithecus aethiops* from 3 groups in the wild	Grooming amongst females
Seyfarth & Cheney (1984)	Experimental	Juvenile and adult female *Cercopithecus aethiops* from a group in the wild	Gromming amongst females and reciprocal altruism
Silk (1982)	Observational	10 adult female *Macaca radiata* from a captive group	Social behavior and patterns of grooming and altruism
Silk et al. (1981)	Observational	29 adult female, 25 immature male, and 13 immature female *Macaca radiata*	Social behavior and affiliation and aggression

(table continues)

TABLE 2. ***Continued***

Author	Study type	Subjects	Variable
Sugiyama (1988)	Observational	1–4 adult male and 7 adult female *Pan troglodytes verus* in a wild group	Social behavior and grooming affiliations
Suomi et al. (1971)	Experimental	30 male and 30 female infant *Macaca mulatta*	Infant responses to partial social isolation
Thierry (1984)	Observational	22 *Macaca tonkeana*	Clasping
Thierry (1986)	Observational	12–20 in each: *Macaca mulatto*, *Macaca tonkeana*, *Macaca fascicularis*	Aggression and postconflict behavior
Tutin (1979)	Observational	9 adult females from a group of 17 male and 24 female *Pan troglodytes schweinfurthii*	Social behavior and female response to copulation
Watts (1995)	Observational	*Gorilla gorilla beringei* Group 1: 4 males, 12 females, 15 juveniles and infants; Group 2: 4 males, 13 females, 16 juveniles and infants; Group 3: 2 males, 7 females, 8 juveniles and infants	Reconciliatory behavior compare to importance of social relationships
Weber (1973)	Observational	Langur *Presbytis entellus*	Observational of tactile communication and relations to group composition and status

from evidence that nonhuman primates in captivity groom equally as much as those in the wild, despite the lack of ectoparasites requiring removal (Ewing, 1935; Suomi, 1990). In addition, monkeys of a lower status are groomed less although they are as susceptible to parasites as are primates of a higher status (Sparks, 1967). Thus, evidence indicates that grooming maintains social relationships between nonhuman primates of every sex, age, and rank. It is interesting to note, however, that although the majority of nonhuman primates socially groom, it is not present among all primate groups. For example, spider monkeys (*Ateles geoffroyi*; Ahumada, 1992) and squirrel monkeys (*Siamiri scureusi*; Robinson & Janson, 1987) do not exhibit grooming behavior. Despite

this, the strong presence of touch in nonhuman primate relations, independent of the amount of ectoparasites, indicates that it plays a greater role than merely the removal of parasites.

An important evolutionary function of grooming is to increase the health of individual conspecifics that are closest in relation to the groomer. In this way, grooming can be considered a prosocial behavior. Close kin are most often the recipients of allogrooming because they are more likely to reciprocate and aid a female when she is in need of help (Borries, Sommer, & Srivastava, 1994; Butovskaya, Kozintsev, & Kozintsev, 1994; Cheney, 1977; Goodall, 1986; Schino, 2001; Seyfarth, 1977). This relationship is especially strong in female nonhuman primates. Grooming helps to remove parasites, maintain social bonds, and—by bringing many females in close proximity—increase the amount of physical protection from predators.

Because survival of infants is vital to the continuation of all nonhuman primate species, grooming is also focused on females of child-bearing age and their infants. Young females are more likely to be groomed because they are in estrous or have an infant (Chadwick-Jones, 1998; Terry, 1970). The well being of the younger females is more beneficial to the troop in terms of their potential to reproduce, compared with older nonhuman primates that are less reproductively successful (Borries et al., 1994). Offspring are also groomed frequently and can account for as much as 20% of a female's total grooming time in bonnet monkeys (*Macaca radiate*), 52% in snow monkeys (*Macaca fuscata*), and 80% of grooming time in chimpanzee (*Pan troglodytes*) mothers with multiple offspring (Goodall, 1986; Gouzoules & Gouzoules, 1987; Koyama, 1973). This amount of grooming directed toward young nonhuman primates not only keeps them physically healthy but also provides stimulation and is thought to enhance the development of a strong attachment with their mother (Gouzoules & Gouzoules; Harlow et al., 1963; Koyama; Nishida, 1979). The bond between the mother and offspring lasts for many years, and relationships between females and adult offspring are not uncommon (Suomi, 1984). Touch serves to strengthen the bond between mother and infant and, as a result, increases the likelihood of survival.

Some researchers believe that touch, rather than primitive vocal calls found in nonhuman primates, is the evolutionary precursor to language in humans (Aiello & Dunbar, 1993; Dunbar, 1995, 1996). In nonhuman primate groups, especially in Old World species, grooming seems to serve the same function that language does for humans because of its communicative functions. Old World species are closer in relation to humans than New World species and are considered less primitive than are New World species. The relationship between language and grooming points to potential cross-species universality in social interactions. These social interactions are thought to initiate, strengthen, and maintain social relationships. As primate groups became increasingly larger, higher levels of processing in the brain were necessary to allow for the increase in interactions (Ehrlich, 2000).

Researchers have found that the number of individuals in a group of primates positively correlates with the size of the neocortex (Aiello & Dunbar, 1993). As the size of the neocortex becomes larger, nonhuman primates retain information about more complex relationships with more animals because an increase in size leads to higher levels of thought and organization. For nonhuman primates living in small groups, grooming could remain as the primary means of communication. In those nonhuman primates that began to live in increasingly larger groups, the capacity of the neocortex increased to allow for the influx of complicated relational information. Ehrlich (2000) found that because grooming is a primary means of communication between nonhuman primates, the increasing difficulty of grooming all the necessary social partners while maintaining other necessary activities such as foraging and protection causes a need for a more efficient means of communication in larger groups. The simultaneous increase in the capacity of the neocortex and group size may have led to the formation of early syntax and the development of language in *Homo sapiens*. When compared with the vast physical and mental modifications that would be necessary for the evolution of nonhuman primate vocal calls into language, it appears that the functional connection between language and touch provides a simpler explanation for the social significance of both (Aiello & Dunbar).

Touch and Status

The large group size of many nonhuman primate troops increases the need for an organized social structure. The primary means by which nonhuman primates, particularly Old World monkeys, retain this complex structure is by grooming (Dunbar, 1991). Most nonhuman primate groups live in multimale, multifemale groups where living is structured and social relationships are established to keep the troop together safely (Aiello & Dunbar, 1993; Harcourt, 1979; Mitchell & Tokunaga, 1976; Smuts, 1987a). A male is typically dominant, followed by other subordinate males, and females usually rank under these males depending on the species. A male that is higher in status has mating access to the females, and a higher ranked female may have preferential access to the male of her choice (Smuts; Sparks, 1967; Terry, 1970). Higher ranked males may also control the movement or eating patterns of the troop. Although these patterns may not hold true in all groups, they are characteristic of a troop with multiple male and female primates (Terry).

In most troops of nonhuman primates, a specific social structure dictates the way each animal lives. Generally, groups are formed by female lineage with the exception of a few species such as chimpanzees (*Pan troglodytes*) and colobus monkeys (*Procolobus badius*), who are bonded through male lineage (Smuts, 1987a). In a female-bonded group, males usually leave the troop at a young age for various reasons, including mating, whereas young females leave if the group is male bonded (Drickamer, 1976). The young primates, either male or female

depending on the species, must then become established in a different group (Smuts, 1987a). Grooming is important to their acceptance in new troops because it helps to develop relationships (Defler, 1978).

In species that reside in small groups, such as the gorilla (*Gorilla gorilla*), the dominant animal is typically a single male sometimes joined by a younger, subordinate male (Harcourt, 1979). They are usually accompanied by several adult females, along with juveniles and infants, to form a closely attached group. Species that live in larger troops often have several high-ranked males who fight for dominance. Females break into intimate familial social groups, similar to the size of a small troop, with infants and juveniles (Drickamer, 1976). Although the social structures are not completely rigid, a dominant male and female can be distinguished in almost every group by their behavior and the treatment they receive from conspecifics.

The underlying social factors of touch are more important to the primate lifestyle than are the actual physical patterns involved in the grooming relationship (Boccia, 1983; Boccia et al., 1982; McKenna, 1978). The social factors involved in grooming are multifaceted and include sex, rank, and time available for grooming. Forming an inclusive grooming model for nonhuman primates is almost impossible given the complex systems established within each species and troop (Barton, 1983). To systematize these complex grooming relationships, the fundamental affiliations between female-female, male-male, and male-female associations must be examined.

Female-female relationships. The complexity of associations between females is unrivaled by any other relationship in nonhuman primate groups. The vast body of information available on the grooming relationships between female nonhuman primates is indicative of the importance of these associations. Because most troops are formed by female lineage, it is essential to the survival of the group that females form grooming associations with other females (Defler, 1978; Sade, 1972). Female-female grooming dyads are the most commonly found relationships among nonhuman primates (Drickamer, 1976; Koyama, 1973; Lindburg, 1973; Perry, 1996; Schino, Aureli, & Troisi, 1988; Sparks, 1967).

In this section, we attempt to synthesize the complex relations of female grooming with the extensive literature on female associations. Seyfarth's (1977) model integrates rank, attractiveness, preference for close relations, and time available for grooming to determine which interactions are most likely. According to this model, high-ranking females receive significantly more grooming than lower ranking females. Grooming a higher ranked female may benefit the groomee with protection in aggressive encounters. However, in most nonhuman primate species, highly ranked females reciprocate less than do females in other ranks (Buirski, Kellerman, Plutchik, Weininger, & Buirski, 1973; Perry, 1996; Sade, 1972; Silk, 1982; Silk, Samuels, & Rodman, 1981; Walters & Seyfarth, 1987). The limited amount of high-ranking females and the unwillingness to

reciprocate in grooming causes primates to turn to others of a similar status, often their relatives, to form relationships that have optimal benefits in the amount of time they are able to groom (Seyfarth, 1977). This pattern of grooming appears most clearly in Old World species such as genus *Macaca* but is also apparent with added complexity in New World species (Gouzoules & Gouzoules, 1987; Seyfarth, 1977, 1980). A meta-analysis of 27 different social groups belonging to 14 different species supports Seyfarth's (1977) model of female grooming in which high-ranked females receive significantly more grooming than do lower ranked females (Schino, 2001).

Nonetheless, the finding that higher ranked females receive grooming more frequently than do lower ranked females has been debated. In some species of monkeys, including the brown capuchin (*Cebus paella*), the wedge-capped capuchin (*Cebus olivaceus*), the blue monkey (*Cercopithecus mitis stuhlmanni*), and the langur (*Presbytis entellus*), females groom conspecifics of different patterns equally and exhibit different patterns of behavior (Borries et al., 1994; di Bitetti, 2000; O'Brien, 1993; Parr, Matheson, Bernstein, & de Waal, 1997; Rowell, Wilson, & Cords, 1991). For example, female langurs (*Presbytis entellus*) groom females of a higher social status more than their own rank only 51% of the time (Borries et al.). Female wedge-capped capuchins (*Cebus olivaceus*) groom down the rank more often than do other females, and higher ranked female wedge-capped capuchins (*Cebus olivaceus*) and rhesus macaques (*Macaca mulatta*) groom more than do other females (Lindburg, 1973; O'Brien). Considering the variations that occur between species in grooming, it is possible that each species has its own pattern of grooming in the status hierarchy dependent on their needs (Sambrook, Whiten, & Strum, 1995) and that tolerance may be more important than the formation of coalitions between different statuses (Henzi & Barrett, 1999). Nevertheless, the modal pattern of grooming is for higher ranked females to be groomed more frequently than lower ranked females.

Although higher ranked females receive more grooming than do other females in general, attraction to kin has a stronger effect on grooming preferences than does rank (Schino, 2001). Kin reciprocate the action more often than do nonkin and form lasting relationships with close relatives (Borries et al., 1994; Cheney, 1977; Defler, 1978; Goodall, 1986; Lindburg, 1973; Perry, 1996; Silk, 1982). Grooming kin may be higher in some species because the groups are established by female lineage. Groups bonded by male lineage have fewer female relations overall and, therefore, lower grooming rates (Cheney, 1992; Goodall). This idea does not completely explain why higher ranked females receive grooming from unrelated, lower ranking females at a disproportionate rate, but it does indicate that the complexity of the female social grooming structure can not be explained by status alone (Silk).

Alliances formed between nonkin females help to maintain group cohesion, especially in large multifemale groups. In an experimental study, a tape-recorded vocalization of a female specific nonkin grivet (*Cercopithecus aethiops*) was

played to another female monkey who was familiar with the tape-recorded monkey (Seyfarth & Cheney, 1984). The vocalization was played in the vicinity of the live female monkey at a time when it was possible that the tape-recorded monkey was near. The live female responded to the call significantly more if she had recently groomed the monkey who made the vocalization than if she had not groomed her, indicating that grooming signifies the formation of an alliance (Seyfarth & Cheney). Although kin grooming is more common, unrelated females commonly form alliances, perhaps to ease intragroup tension and maintain the overall social structure (Cheney, 1977; Seyfarth & Cheney).

Male-male relationships. Intense grooming between males does not take place as commonly as it does in female dyads in most nonhuman primate species (Drickamer, 1976). Young males often leave their mother's troop and then must establish themselves in another troop, which results in nonrelated males becoming part of the same troop (Smuts, 1987a). Without relation and with the competition for rank, many male relationships are strained. Many troops have only a single dominant male or may only affiliate with a male during mating season, resulting in the isolation of males. The exception is male chimpanzees, who are four times more likely to groom than are females and have better quality relationships amongst themselves compared with females, which may be a result of a troop structure derived from male lineage rather than female lineage (Chadwick-Jones, 1998; Goodall, 1986; Nishida & Hiraiwa-Hasegawa, 1987; Sugiyama, 1988).

Although touch among males is uncommon when compared with that among females, even rare occurrences of touch help to maintain relationships. Whether there are 2 males or 20, dominance relationships dictate the amount of touch found between males. Dominant males receive the most grooming without reciprocation of any primate, male or female (Borries et al., 1994; Terry, 1970). Juveniles can approach the dominant male to groom him, but they must be willing to do this without reciprocation. Doing so establishes the juvenile male as an ally rather than as an enemy (Buirski et al., 1973; Chadwick-Jones, 1998; Nishida & Hiraiwa-Hasegawa, 1987).

Although competition for mating or dominance impedes associations among males, the struggle to become dominant can initiate affiliation. Grooming is used between male chimpanzees (*Pan troglodytes*), for example, to avoid aggression when there is competition for dominance because it calms both involved and may turn their opposition into affiliation (Goodall, 1986). Troops of gorillas (*Gorilla gorilla*) are relatively small and have one silverback male, the dominant, and possibly one or two subordinate blackback males, but it is still beneficial for the males to form alliances (Harcourt, 1979). Because small troops operate independently, it is beneficial for the males within a group to cooperate, with or without touch, and remain allies rather than face the constant threat of aggression alone (Harcourt).

Male-female relationships. Males and females of any primate species exhibit some form of touch, but the amount and situation of touch varies across species (Drickamer, 1976). The establishment of male-female relationships is essential to the vitality of nonhuman primate populations. Cooperation between the sexes helps to maintain the stability of the social structure and is used to initiate copulation.

Status is an important factor in the male-female relationship in terms of who initiates the touch and how it is administered. In many species, both male and female dominant primates receive more grooming than do other members of the troop (Butovskaya et al., 1994; Izawa, 1980; Sparks, 1967; Terry, 1970). The status of the groomee determines who will be groomed by whom, on what part of the body, and how long the groomer will stay without reciprocation (Sparks). This relationship can be as extreme as it is in the tufted capuchin (*Cebus apella*), where the dominant male and female receive twice as much grooming from males and females as they give and are involved in 63% of all grooming bouts (Robinson & Janson, 1987).

In sexually dimorphic species, females typically groom males more often than is reciprocated, but female control of grooming is less evident in sexually monomorphic species (Mitchell & Tokunaga, 1976). This may account for some observed species differences, and although these differences can be vast, males and females relate in different ways depending on their status and the size of the group in which they live. Females participate in social grooming more than do males in almost every species, and males are groomed more than they reciprocate (Harcourt, 1979; Mitchell & Tokunaga).

Grooming and Stress

Nonhuman primates often experience stress in their environments, whether it is in a zoo, a primate laboratory, or in the wild. In social situations, nonhuman primates use touch to modulate stress. Specifically, grooming relieves the stress associated with aggression, social relationships, mounting, sexual mounts, and embraces, which then, in turn, promotes the formation and maintenance of relationships (Goodall, 1986; McKenna, 1978; Terry, 1970). Touch, then, promotes physical and emotional homeostasis (de Waal, 1993).

Touch among conspecifics is especially effective during times of social agitation (Weber, 1973). As mentioned, touch between males of most species is not common. However, among adult male chimps, grooming is observed when there is tension that relates to their status in the troop (Goodall, 1986). This may relieve the stress that these males may experience because of changes or challenges to their social positions in the hierarchy. Female chimpanzees may act as mediators between two aggressive males and coax one or both of them to stop engaging in the aggressive act by grooming them (Goodall). These tactile interactions modulate socially induced stress by directly interrupting stressful stimuli in nonhuman primates.

Tactile stroking is more frequent among nonhuman primates than is picking or other forms of grooming even though it is less efficient in removing parasites. This may be because of its apparent calming effect (Boccia, 1989). Interactions between two animals can cause anxiety for either of them, but the presence of grooming reduces an animal's heart rate and results in fewer displacement activities to reduce stress (Aureli, Preston, & de Waal, 1999; Boccia, Reite, & Laudenslager, 1989; Schino, Schucchi, Maestripieri, & Turillazzi, 1988).

Touch in Reconciliative Acts Following Aggression

Aggression can be potentially dangerous in nonhuman primate groups because it threatens the victim personally as well as the social structure in which the victim plays a part. Touch is often involved in aggressive acts and includes slapping, kicking, biting, and clasping. The frequency of touch in aggressive acts varies significantly between species (Bernstein, Williams, & Ramsay, 1983; Goodall, 1986; Gust & Gordon, 1993; Kaplan, 1978; Ren et al., 1991; Thierry, 1984).

The role of touch is central to the resolution of hostility and aggression (Silk, 2002). One of the most common strategies for nonhuman primates to resolve conflicts is through reconciliation. Reconciliation, which has been documented in over 20 nonhuman primates species (Aureli & de Waal, 2000), may be favored by natural selection because it resolves conflicts quickly and unambiguously (Silk). Reconciliation is thought to serve several potential functions including (a) to preserve evolutionarily valuable social relationships among conspecifics, (b) to maintain group cohesion, and (c) to obtain short-term objectives including access to resources (Aureli, 1992; Aureli & de Waal; Aureli, Van Schaik, & Van Hooff, 1989; de Waal, 1993; Gust & Gordon, 1993; Kutsukake & Castles, 2001; Silk; Terry, 1970).

Touch plays a significant role in the achievement of these goals and is commonly accepted as an important postconflict strategy (Boccia et al., 1982; de Waal, 1993; Matheson, 1999; Silk, 2002; Thierry, 1986; Watts, 1995). Common touches in reconciliation include grooming, mounting, and clasping, which is similar to a mount or embrace and is carried out at various angles (Thierry, 1984). The rates of reconciliation vary between species but usually occur within minutes of the actual conflict (Aureli et al., 1989; de Waal, 1993; Gust & Gordon, 1993). In one study, researchers observed a higher frequency of nonaggressive contacts between captive long-tailed macaques after conflict, compared with a matched control period (Aureli et al.). Affiliative contacts, including touch, typically occurred in the first 5 min following conflict and returned to baseline levels.

Several studies indicate that contact during reconciliation has adaptive social and physiological effects (Aureli et al., 1989; Boccia et al., 1989; Cords, 1993; Das, Penke, & Van Hooff, 1998). In one study, lower ranking monkeys were significantly more likely to drink next to higher ranking monkeys after conflict if

they had touched each other, compared with a nontouching control group (Cords). In another study, grooming, and specifically stroking, of the victim by the aggressor after an aggressive encounter significantly reduced heart rates, whereas other postconflict acts did not (Boccia et al.). Several studies indicate that other markers of stress and anxiety such as self-scratching are modulated (e.g., Aureli et al.). Reconciliation is thought to reduce stress because it reduces the uncertainty that subsequent aggression between conspecifics will transpire (Silk, 2002).

The Role of Touch in Sexual Relations

The act of copulation in nonhuman primates necessarily involves touch between males and females, but touch plays a central role in precursory and subsequent interactions as well. Many activities are dedicated to the formation of appropriate sexual behavior from a young age to stimulate and develop behavior necessary for copulation. Mating season is generally the period of most frequent contact between males and females, although significant species differences exist (D'Amato, Troisi, Schucchi, & Fuccillo, 1982).

Touch before copulation. Copulation usually involves the formation of a consort relationship between a male and a female. The consort relationship between the sexes may last from a few minutes to a few days and is unique because of the increased time they spend together during this period (Drickamer, 1976; Hinde, 1976; Nadler, Herndon, & Wallis, 1986). Males direct more attention to estrous females than to nonestrous females, whether it is through grooming or aggression (Terry, 1970). Physical signs, such as swelling of the anogenital region, a pink or red coloring around the genitals, and a distinct odor make evident the females in estrous (Doyle, 1974; Nadler et al.). These signs lead to increased attention from males in the form of licking and grooming of the anogenital region (D'Amato et al., 1982; Doyle; Sparks, 1967). All females become more desirable during estrous, but the amount of attention that females receive may relate to their status more than their state of estrous (Bowman, Dilley, & Keverne, 1978).

The amount of grooming between males and females increases during mating season (D'Amato et al., 1982; Drickamer, 1976; Jolly, 1972; Maestripieri & Wallen, 1997). The dominant male is groomed often by the various females of the group, but the male usually favors a specific groomer (Harcourt, 1979; Izawa, 1980; Lindburg, 1973; Oki & Maeda, 1973; Schino, Aureli, et al., 1988; Schino, Schucchi, et al., 1988). In gorillas (*Gorilla gorilla)*, the only male permitted to mate with the estrous females is the silverback (Nadler et al., 1986). A female who is more attentive to the male during mating season often gains priority in mating and the possible establishment of a relationship (D'Amato et al., 1982). Females tend to choose males who have reciprocated their attention in grooming and are less aggressive than others (Goodall, 1986; Michael, Bonsall, & Zumpe,

1978; Smuts, 1987b; Tutin, 1979). All of these factors contribute to the formation of a sexual relationship between males and females and influence the chances of reproduction.

Touch during and after copulation. In many species, the male mounts the female several times to achieve ejaculation in between which the male and female engage in grooming (Doyle, 1974; Michael et al., 1978). After copulation, grooming and licking are frequently observed between primates (Blurton Jones & Trollope, 1968; Doyle; Terry, 1970). Because copulation can be perceived as the climax of sexual tension, grooming and licking are thought to serve the purpose of reducing built-up tension (Terry). After mating season, male-female grooming returns to baseline levels.

Attachment

Infant primates form an attachment to their mother or a surrogate mother within the first few months of life, which helps them to develop both physically and emotionally (Bowlby, 1978; Harlow, 1958; Harlow & Harlow, 1962, 1969). Without normal attachment patterns, nonhuman primate infants show anomalous social behaviors with conspecifics (Harlow; Harlow & Harlow, 1962; Schlottmann & Seay, 1972; Seay, Hansen, & Harlow, 1962).

Many psychoanalysts once believed that attachment between the infant and mother existed because of the primary drives for food and thirst reduction and the oral fixation with the mother's breast (Harlow, 1958). Harlow's famous studies with infant rhesus macaques (*Macaca mulatta*) demonstrated that infants find contact comfort more appealing than feeding alone, indicating that touch, not food, may be the primary mechanism of attachment (Harlow; Harlow & Harlow, 1962). Researchers removed infant monkeys from their mothers at birth or soon after and they were raised with surrogate mothers, either cloth or wire. The infants spent more time on the cloth mother even if the wire one was feeding them. In addition, infants ran to the cloth surrogate when frightened, and only the infants raised on a cloth surrogate showed a strong attachment to it (Harlow; Harlow & Harlow, 1962). Infants also chose the cloth surrogate more often over a heated wire surrogate (Harlow & Suomi, 1970). Infants became very attached to the surrogate mother and exhibited normal clinging and ventral-ventral contact behavior (Harlow; Harlow & Harlow, 1962; Seay et al., 1962; Suomi, 1984). These experiments indicated that contact comfort and attachment are primary, not secondary, to food consumption as psychoanalysts once thought.

Similar to human infants, the attachment behavioral system in nonhuman primates is typically activated when the infant is separated from its mother (Belsky, 1999; Bowlby, 1969). During separation, infants demonstrate a variety of behaviors including abnormal posture and movement, poor integration of motor re-

sponses, deficits in communication, and cooing and shrieking (Jensen & Tolman, 1962; Mason, 1973; Rosenblum, 1971; Suomi, Harlow, & Kimball, 1971). Physiological responses to separation include disturbances in heart rate, changes in night body temperature, decreased overall sleep time, elevated cortisol levels, changes in neurotransmitter levels, and depressed immune system functioning (Coe, Mendoza, Smotherman, & Levine, 1978; Gunnar, Gonzalez, Goodlin, & Levine, 1981; Kaplan, 1978; Kraemer, Ebert, Schmidt, & McKinney, 1989; Levine & Stanton, 1990; Mendoza, Smotherman, Miner, Kaplan, & Levine, 1978; Reite & Capitiano, 1985; Reite, Kaemingk, & Boccia, 1989; Reite & Short, 1978; Reite, Short, Kaufman, Stynes, & Pauley, 1978; Sackett, Bowman, Meyer, Tripp, & Grady, 1973).

Separation is usually reparable after the mother and infant come into contact again (Jensen, 1965; Jensen & Tolman, 1962; Suomi et al., 1971). Although the return to proximity with the mother reduces arousal after separation, touch further down-regulates the effects of separation and decreases the physiological arousal it causes in the infant (Levine & Stanton, 1990). One study showed that cortisol levels of *Rhesus macacas* became elevated as the period of separation became longer, but cortisol levels returned to normal after being in contact with the mother (Levine & Stanton).

Summary and Conclusions

Touch plays an important role for nonhuman primates. We have discussed how touch is related to status in the troop, its effects on stress, its role in sexual relations between conspecifics, and its fundamental importance in attachment. Nonetheless, there are significant gaps in our understanding that merit attention. One of the most significant deficits of the reviewed research is that phenomena, such as infant attachment behavior toward a surrogate mother, are studied with one species, rhesus macaques (*Macaca mulatta*) in this case, but not in other nonhuman primate species. Vast differences likely exist among species of primates.

There are several domains of touch in nonhuman primates that may be fruitful for future investigation. Because the actual presence of reconciliation is currently disputed, this is one area that would greatly benefit from further research. Inducing aggressive acts and reconciliation in different combinations of kin, nonkin, and sex will lead to a better understanding of the mediating factors influencing the role of touch during reconciliation. Another fundamental question of touch in primates yet to be answered is its evolution. Relatively recent researchers presented touch in nonhuman primates as the precursor to language in humans (Aiello & Dunbar, 1993; Dunbar, 1995, 1996). This research is disputed, but information as to the precursor of language will have a great effect on the way touch is viewed in nonhuman primates, either as a necessary social mechanism or not. Although further research is needed to better understand the purpose

of touch in nonhuman primates, ample evidence indicates that touch serves an essential role in the social life of nonhuman primates.

TACTILE STIMULATION IN RATS

The effect of tactile stimulation on rats has garnered the interest of researchers for over 5 decades (Bernstein, 1952; Denenberg, 1962b; Levine & Stanton, 1984; Meaney, 2001; Weinberg & Levine, 1977). In this section, we address the effects of tactile stimulation on rodent emotionality, learning, memory, novelty-seeking behavior, stress, and attachment. We chose to review a literature only if tactile stimulation was manipulated as the independent variable and the sample was composed of a species of rat. Table 3 presents the empirical studies that focused on the effects of touch in rats.

Researchers often employ two broad types of tactile stimulation when investigating its effects: (a) human handling and (b) maternal behavior. The first, human handling, is one of the primary means by which the effects of touch are investigated. Typically, handling consists of removing the pup from the nest for a brief time period, anywhere from 3 to 15 min, and then returning it to the nest (Levine, 1957). The second type of tactile stimulation is maternal behavior. The primary means by which rat mothers provide tactile stimulation to their pups is by maternal licking or grooming and nursing. Licking and grooming (LG) occur most often during nursing, specifically during arched-back nursing (ABN; Caldji, Diorio, & Meaney, 2000; Caldji et al., 1998; Stern, 1996), which involves a position that accommodates for litter mass (Caldji et al., 1998; Stern). Individual differences in LG and ABN have been identified in the literature (Bredy, Weaver, Champagne, & Meaney, 2001; Caldji et al., 1998; Meaney, 2001). In fact, such dams are often referred to in the literature as *high or low licking/grooming-arched back nursing* (LG-ABN) mothers (Caldji et al., 1998; Meaney). Interestingly, both high and low LG-ABN mothers spend the same amount of time with their pups (Caldji et al., 1998; Meaney), and the changes induced by maternal LG-ABN transcend generations; the offspring of low LG-ABN mothers become low LG-ABN mothers, and likewise for high LG-ABN offspring and mothers (Bredy et al.; Caldji et al., 1998; Meaney).

Besides touch, researchers often include a variety of other variables as part of studies that investigate the consequences of touch, including age, intensity of handling, species or lines or strains, sex differences, and genetic background. Levine and Wetzel (1963) addressed the problem of differences in genetic background specifically, stating that if a general set of principles regarding the consequences of infantile stimulation was desired, either more strict standards regarding genetic information were in order, or the problem of genetics should be ignored. We take the latter part of Levine and Wetzel's suggestion and apply it to many of the aforementioned variables, not merely genetics. This heterozygous

population is necessary to synthesize the literature and make general conclusions. Deviations from these generalizations will be noted.

Emotionality and Touch

The literature on touch and emotionality typically focuses on displays of negative emotionality, which is indexed by analyzing a wide array of factors including defecation, ambulation, crouching, and startle response in several different paradigms. The overwhelming conclusion of a vast amount of research establishes handling as one of the most powerful means of modulating negative emotionality (Ader, 1959; Costela, Tejedor-Real, Mico, & Gibert-Rahola, 1995; Fernández-Teruel, Escorihuela, Driscoll, Tobeña, & Battig, 1992; Garbanati et al., 1983; Levine, Haltmeyer, Karas, & Denenberg, 1967; Núñez et al., 1995; Ploj et al., 1999; Tejedor-Real, Costela, & Gibert-Rahola, 1998; Weinberg, 1987). In an open field test, for example, handled rats showed greater movement and more rearing than nonhandled rats, indicating both more positive emotion and less negative emotion displayed by the handled group (Ploj et al.). However, it should be noted that there is contradictory evidence indicating that temperature changes during removal of the cage for handling is responsible for the handling effect; some investigators believe that temperature mediates the effect (e.g., Denenberg, Brumaghim, Haltmeyer, & Zarrow, 1967; Schaefer, 1962, 1963, 1968), whereas others do not (e.g., Williams, Bailey, & Lee, 1975).

The breadth of research in this domain necessitates separate discussions of the major variables that moderate the effects of handling on emotionality.

Age of handling. The age at which handling is provided is a crucial variable mediating the effects of touch (Ader, 1959; Denenberg, 1962a; Levine & Otis, 1958). Researchers have found that rats handled in the period between birth and weaning exhibit less negative emotionality compared with rats handled later (Bernstein, 1952; Diamond, 1990; Levine, 1956, 1959; Núñez, Ferré, Escorihuela, Tobeña, & Fernández-Teruel, 1996; G. J. Schaefer & Darbes, 1972; Schaefer, 1963). These findings have led to the development of a critical period hypothesis. The preponderance of literature indicates that tactile stimulation has its greatest impact when administered within a time window, particularly the period between birth and weaning, but perhaps more specifically during the first week of life (Denenberg, 1962a; Diamond, 1990; Levine, 1956; Levine & Alpert, 1959; Levine & Otis, 1958; Schaefer, 1963).

Quality of handling. The quality of touch used during handling often differs among studies. Research indicates that gentle handling yields animals with the lowest levels of emotional reactivity followed by harsh handling, leaving nonhandled controls to be the most negatively emotional (Ader, 1959; Eells, 1961). Likewise, other work has shown that certain types of tactile stimulation are more pleasing to rats

TABLE 3. Studies of Tactile Communication in Rats Classified According to Subjects, Experimental Manipulation (Including the Days After Birth the Treatment was Administered and the Type of Treatment), and the Examined Variables (Including When the Variables Were Measured)

		Experimental manipulation		Variable	
Author	Subjects	Time (days)	Type	Time (in days unless noted)	Type
Ader (1959)	104 albino	23–53 or 136–166	Handling	68–87 or 181–200	Emotionality (age, quality)
Ader (1968)	177 Charles-River	1–20 or 21–40	Handling, shock	90	Stress (corticosterone)
Bernstein (1952)	50 albino	Weaning–60 or 50–60	Handling	60	Emotionality (age)
Bernstein (1957)	50 Sprague-Dawley albino	21–60	Handling	60	Learning and memory
Bodnoff et al. (1987)	Long Evans hooded	1–21	Handling	100	Novel environment and substances
Bredy et al. (2001)	n/a	n/a	n/a	n/a	Cognitive (maternal) and stress (HPA)
Caldji, Diorio, et al. (2000)	n/a	n/a	n/a	n/a	Emotionally (maternal), novel environment and substances (maternal), and stress (CRH, corticosterone, Gr)
Caldji, Francis, et al. (2000)	M Long-Evans	1–14	Handling maternal, separation	90–120	Novel environment and stress ($GABA_A$/CBZ)
Caldji et al. (1998)	Long-Evans hooded	1–10	Maternal interaction	100	Emotionality (maternal, maternal mediation), novel environment and substances (maternal), stress (CRH)
Campbell & Spear (1999)	136 Sprague-Dawley	1–12	Handling	21+	Novel environment, stress (corticosterone), and addiction
	131 Sprague-Dawley	1–12	Handling	21+	Novel environment, stress (corticosterone), and addiction

	139 Sprague-Dawley	1–12	Handling	21+	Novel environment, stress (corticosterone), and addiction
Costela et al. (1995)	20 Wistar	1–21	Handling	47–50	Emotionality and depression
Denenberg (1962a)	69 Harvard Wistar	1–3, 3–5, 1–5, 6–8, 8–10, 6–10	Handling	69 days	Emotionality (age, duration)
Denenberg (1962b)	n/a	n/a	n/a	n/a	Learning
Denenberg et al. (1967)	Purdue-Wistar	2	Handling	2	Emotionality (temperature), and stress (corticosterone)
Denenberg & Grota (1964)	44M Purdure-Wistar	1–20	Handling	100	Novel environment
Denenberg & Karas (1960)	36 Harvard Wistar rats	1–25	Handling	62	Learning
	36 Harvard Wistar rats	1–10, 11–20, 1–20, 11–15, 16–20	Handling	62	Learning
	48 Harvard Wistar rats	1–21, 1–10 11–20, 1–20	Handling	60	Learning
Denenberg & Karas (1961)	Harvard Wistar	1–10, 11–20, or 1–20	Handling	60–69	Emotionality (duration)
Denenberg & Morton (1963)	174 Purdue-Wistar	1–24	Handling	70	Novel environment
Denenberg et al. (1966)	92M Purdue-Wistar	1–20	Handling, environment	70–74	Novel environment
Denenberg & Smith (1963)	154 Purdue-Wistar	11–20	Handling, shock	50, 100, 150, or 200	Emotionality (duration, intensity)
Diamond (1990)	54 M Long-Evans	1-testing	Litter Size, Environment	14, 19, or 28	Emotionality (age)
Eells (1961)	10 M albino Sprague-Dawley	15–62	Handling	62–79	Emotionality (quality, consistency)
Escorihuela et al. (1994)	Sprague-Dawley	1–21	Handling	180, 270, and 390	Learning

(table continues)

TABLE 3. ***Continued***

Author	Subjects	Experimental manipulation		Variable	
		Time (days)	Type	Time (in days unless noted)	Type
Fernández-Teruel et al. (1991)	37 RHA/Verh, 37 RLA/Verh	1–21	Handling	30	Novel environment
Fernández-Teruel et al. (1992)	n/a	n/a	n/a	n/a	Cognitive (age)
Ferré et al. (1995)	40F Sprague-Dawley	1–22	Handling	40, 120	Emotionality (intensity) and and novel environment
Francis et al. (1999)	n/a	n/a	n/a	n/a	Stress ($GABA_A$/CBZ)
Francis & Meaney (1999)	n/a	n/a	n/a	n/a	Stress (HPA, $GABA_A$/CBZ, Gr)
Gabriel et al. (2002)	Sprague-Dawley	2–15	Handling, prenatal ethanol exposure	60 or 390–420 (2 or 13–14 months)	Memory, cognitive (age), stress (Gr), and prenatal alcohol
Gabriel & Weinberg (2001)	Sprague-Dawley	2–15	Handling, prenatal ethanol exposure	35	Novel substances and prenatal alcohol
Gabriel et al. (2000)	Sprague-Dawley	2–15	Handling, prenatal ethanol exposure	120–150	Stress (ACTH, corticosterone) and prenatal alcohol
Hilakivi-Clarke et al. (1991)	67 male Wistar rats	5–20	Handling, isolation	59–60, 75, 80–92, 92–97	Addiction
Hofer (1995)	n/a	n/a	n/a	n/a	Attachment
Hofer & Shair (1980)	n/a	n/a	n/a	n/a	Attachment

Iny et al. (1987)	Long-Evans	3	Handling	3	Stress (HPA)
Karas & Denenberg (1961)	280 Harvard Wistar rats	1–10 or 1–20	Handling	51–60	Emotionality (duration)
Kemeny (2003)	n/a	n/a	n/a	n/a	Stress
Kuhn & Schanberg (1998)	n/a	n/a	n/a	n/a	Emotionality
Lee & Williams (1976)	15 black-hooded rats (strain PVG/C)	1–6	Handling	6	Maternal interaction
Levine (1956)	48 Sprague-Dawley	1–20, or 50+	Handling	71	Emotionality (age, quality) and learning
Levine (1957)	27 M Sprague-Dawley Holtzman	1–20	Handling	70	Stress (ACTH)
Levine (1959)	141 Sprague-Dawley albino rats	1–20	Shaking	21	Emotionality (age, maternal mediation) and learning
Levine (1960)	n/a	n/a	n/a	n/a	Stress
Levine (1962a)	n/a	n/a	n/a	n/a	Emotionality (maternal mediation), learning, and leukemia
Levine (1962b)	n/a	n/a	n/a	n/a	Leukemia
Levine (1967)	81 Long-Evans	0, 10, or 20	Handling	42	Stress (corticosterone)
	92 Long-Evans	1–20	Handling of mother during her infancy, handling	42	Stress (corticosterone)
Levine & Alpert (1959)	60 albino Sprague-Dawley	1-day prior to experimental day	Manipulation	10, 12, or 14	Emotionality (age)
Levine et al. (1957)	65 Sprague-Dawley	1–15	Handling	16	Stress (HPA)
Levine et al. (1967)	312 Purdue-Wistar rats	1–20	Handling	80	Emotionality and novel environment
Levine & Otis (1958)	50 Sprague-Dawley	1–21 or 21–42	Handling	51	Emotionality (age)
Levine & Stanton (1984)	n/a	n/a	n/a	n/a	Novel environment (maternal) and stress (HPA)

(table continues)

TABLE 3. ***Continued***

Author	Subjects	Experimental manipulation		Variable	
		Time (days)	Type	Time (in days unless noted)	Type
Levine & Stanton (1990)	n/a	n/a	n/a	n/a	Stress (HPA, corticosterone)
Levine & Wetzel (1963)	20 males each of Sprague-Dawley, Harlan Long Evans, and Rockland Long Evans	1–21	Handling	~90	Attachment
Liu et al. (2000)	Unknown	Unknown	Maternal interactions	Unknown	Cognitive (maternal)
Liu et al. (1997)	Norway	1–10	Handling, maternal interaction	Adults	Stress (HPA, ACTH, Gr)
Meaney (2001)	n/a	n/a	n/a	n/a	Emotionality (maternal mediation), cognitive (maternal), and stress (HPA)
Meaney, Aitken, et al. (1991)	F Long-Evans	1–21	Handling	6, 12, or 24 months	Memory, cognitive (age), and stress (corticosterone)
Meaney et al. (1985)	Long-Evans hooded	1–21	Handling, postweaning housing	120–150	Stress (corticosterone, Gr)
Meaney et al. (1988)	M Long-Evans rats	1–22	Handling	Adults	Stress (Gr)
Meaney, Mitchell, et al. (1991)	n/a	n/a	n/a	n/a	Memory and stress (HPA, corticosterone, Gr, hippocampus)
Núñez et al. (1996)	M Sprague-Dawley	1–22	Handling	120, 210, or 330	Emotionality (age, intensity) and stress (HPA, CRH)

Núñez et al. (1995)	40/60 F Sprague-Dawley	1–22	Handling	40/105	Emotionality and learning
Pfeifer et al. (1973)	67 M Purdue-Wistar rats	1–20	Handling	35, 100, and 230	Stress (HPA)
Pfeifer et al. (1976)	288 M Purdue-Wistar rats	1–20	Handling	35	Stress (corticosterone)
Ploj et al. (1999)	20 M Sprague-Dawley	1–21	Handling	90	Emotionality and stress
Sapolsky (2000)	n/a	n/a	n/a	n/a	Stress
Schaefer & Darbes (1972)	48 Holtzman albino rats	8–21 and 22–53	Handling and housing, respectively	42–45 (open field), 45–53 (food/water deprivation)	Emotionality (age, intensity)
Schaefer (1962)	n/a	n/a	n/a	n/a	Emotionality (temperature)
Schaefer (1963)	Sprague-Dawley	Varied	Handling, maternal separation	Varied	Emotionality (temperature, age, maternal mediation)
Schaefer (1968)	n/a	n/a	n/a	n/a	Emotionality (temperature)
Schanberg & Field (1987)	n/a	n/a	Maternal separation	n/a	Emotionality
Schell & Elliott (1967)	5M and 8F Sprague-Dawley	Birth-weaning	Handling and shock	60	Emotionality (intensity)
Smythe et al. (1994)	Long Evans Hooded	Prenatal 13–17, 1–14	Prenatal stress, handling	120	Prenatal stress
Stanton et al. (1987)	99, 88, or 93 Laboratory rats	n/a	Maternal separation, deprivation, suckling	12, 16, or 20 respectively	Novel environment (maternal) and stress (HPA)
	36, 38, or 38 lab rats	n/a	Maternal separation, deprivation, suckling	12, 16, or 20 respectively	Novel environment (maternal) and stress (HPA)

(table continues)

TABLE 3. ***Continued***

Author	Subjects	Experimental manipulation		Variable	
		Time (days)	Type	Time (in days unless noted)	Type
	59, 63, or 74	n/a	Maternal separation, deprivation, suckling	12, 16, or 20 respectively	Novel environment (maternal) and stress (HPA)
Stern (1996)	n/a	n/a	n/a	n/a	Attachment
Tejedor-Real et al. (1998)	80 male albino Wistar	1–21	Handling, drug administration	60	Emotionality and depression
Wakshlack & Weinstock (1990)	Albino rats (Sabra strain)	Prenatal, and 1–21	Prenatal stress, handling	35–45 (open field), 55–60 ("Plus" maze), 90 (rotation)	Prenatal stress
Weinberg (1987)	240 M/F Sprague-Dawley	1–14	Handling, prenatal stress	60–80	Emotionality, stress (HPA), and addiction
Weinberg & Gallo (1982)	Offspring of 46 Sprague-Dawley	2–21	Handling (after prenatal ethanol)	39	Prenatal alcohol
Weinberg et al. (1995)	Sprague-Dawley	2–15	Handling	70–100	Cognitive (age) and prenatal stress prenatal alcohol

Weinberg, Smotherman, et al. (1978)	236 F Sprague-Dawley × Long-Evans crosses	2–15	Handling	90–122	Novel substances and attachment
Weinberg & Levine (1977)	32M/32F Sprague-Dawley × Long-Evans crosses	2–15	Handling, shock	90	Stress (corticosterone)
Weinberg, Krahn, et al. (1978)	48M/48F Sprague-Dawley × Long-Evans crosses	2–17	Handling	60	Novel environment
Weinberg et al. (1980)	32 F Sprague-Dawley × Long-Evans crosses	2–15	Handling	90	Novel substances and stress (corticosterone)
Weiner et al. (1987)	64M/64F Wistar	2–22	Handling	85–100	Learning
Wells et al. (1969)	31M/26F hooded rates	1–20	Handling (stimulus variation)	90 +/– 2	Learning
Werner & Anderson (1976)	34 albino rats	Unknown for 21 day period (adult)	Handling	After 21 day period	Emotionality (quality)
Williams et al. (1975)	30M/30F black hooded rats	14–21	Handling (no maternal interaction)	53 +/– 2	Emotionality (temperature, maternal dediation) and novel environment

Note. ACTH = adrenocorticotropic hormone; CBZ = central benzodiazepine; CRH = corticotropin releasing hormone; GABA = Gamma-amino butyric acid; Gr = glucocorticoid receptors; HPA = hypothalamic-pituitary-adrenal axis; RHA = Roman high-avoidance rat; RLA = Roman low-avoidance rat.

and lead to different behaviors; rats that have been stroked and scratched while in their home cage will choose a hand as opposed to restraint, whereas rats who have been held and stroked, will not choose the hand (Werner & Anderson, 1976). Thus, not all types of tactile stimulation yield the same results.

Duration and consistency of handling. The relationship between duration of rat handling and emotionality has also been a variable of interest to researchers (Denenberg & Karas, 1961; Karas & Denenberg, 1961). Some amount of handling in infancy yields rats that are more emotionally stable than no handling at all (Levine, 1956), and the number of days of handling affects later emotionality (Denenberg, 1962a); negative emotionality typically decreases as handling increases (Denenberg & Karas) although increasing quantity is not always beneficial to the rat. In one study, researchers concluded that 20 days of handling reduces the emotionality of the rat to such an extent that performance became impaired (Denenberg & Morton, 1963). Perhaps for this reason, spaced handling is more adaptive than massed handling (Karas & Denenberg).

Intensity of the testing paradigm. Another variable interacting with the effects of touch is the intensity of the testing paradigm. Handling effects are more prominent when the testing situation is more anxiogenic and involves strong conflict (Ferré et al., 1995; Núñez et al., 1996). Moreover, the introduction of new and stressful experiences may alter emotionality from the baseline established by handling or lack thereof (Denenberg & Morton, 1963).

Males and females differ in their emotional reactivity. This gender difference comes into play when discussing the intensity of the testing situation because it varies across testing paradigms. Males are more reactive to mild stress but are more resilient to severe stress than are females (Schaefer & Darbes, 1972; Schell & Elliott, 1967). As a result, the testing situation and additional noxious stimuli (along with gender) must be taken into account in addition to handling when investigating emotionality.

Maternal mediation hypothesis. Maternal separation and reunion is another prominent factor that cannot be overlooked when considering the effects of handling on emotionality. Human handling changes the way in which mothers interact with their pups and provides a separation period between the two. Such changes lead to confusion regarding the effect of handling. Is the tactile stimulation provided by humans alone influencing the emotionality of the pups, or do maternal factors also come into play? There is no broad consensus on the answer to this question. Some believe that there is little evidence to indicate that maternal interaction (or lack thereof) mediates the effects of handling (Lee & Williams, 1976; Levine, 1959, 1962a; Meaney, 2001; Schaefer, 1963; Williams et al., 1975). Indeed, mothers typically are only separated for up to 30 min at a time, so handling is not an abnormally long separation (Meaney). However, oth-

ers disagree and hold that maternal interaction plays a key role in mediating the effects of handling on emotionality (e.g., Caldji et al., 1998).

There is clear evidence that maternal tactile stimulation influences negative emotionality. A number of investigations indicate that tactile stimulation from high LG-ABN mothers modulates the negative emotionality of their pups (e.g., Caldji, Diorio, et al., 2000; Caldji et al., 1998). However, the question remains, which components of maternal interaction (e.g., food, touch, temperature) modulate negative rat emotionality? Data indicate that tactile stimulation is the predominate facet of the maternal interface—not merely the provided food or temperature changes induced by the presence of the mother (Caldji et al., 1998; Kuhn & Schanberg, 1998). Caldji et al. (1998) found that both low- and high-LG-ABN mothers spend the same amount of time with their pups. However, high LG-ABN pups show reduced negative emotionality, indicating that more than just maternal presence is necessary to provide enough tactile stimulation to effectively lower negative emotionality (Caldji et al., 1998). When pups are separated from their mothers for long periods of time, researchers often observe increases in negative emotionality. However, stroking the pups in a manner similar to the touch that they would receive from their mother reverses the deficits (i.e., increased defecation) resulting from maternal separation (Schanberg & Field, 1987). This supports the hypothesis that tactile stimulation is the essential component of maternal contact.

Learning, Memory, and Touch

There is a significant body of empirical support indicating that handling improves learning and memory (Bernstein, 1957; Escorihuela, Tobeña, & Fernández-Teruel, 1994; Levine, 1956, 1959, 1962a; Núñez et al., 1995; Weiner, Feldon, & Ziv-Harris, 1987; Wells, Lowe, Sheldon, & Williams, 1969). Researchers have uncovered variables that moderate the effects of touch on learning, particularly the duration of tactile stimulation administered, the parameters of the testing situation, and the age at which rats are tested. Some researchers have found a curvilinear relationship between amount of handling and adult learning, indicating that a certain peak amount of stimulation can be reached before handling begins to diminish learning (Denenberg, 1962b; Denenberg & Karas, 1960). Núñez et al. found that handled rats performed better when the task was difficult than when it was easier. The increased learning ability of handled rats over nonhandled rats becomes clearer as the task becomes more difficult.

Researchers have also focused specifically on the effects of tactile stimulation on memory. For example, Bernstein (1957) looked at retention following 20 errorless trials of exiting a t-shaped apparatus and receiving a food reward. Handled rats made fewer errors than did nonhandled rats, indicating that handling had improved retention. Handling also reduces spatial memory impairments that become more pronounced with age (Meaney, Aitken, Bhatnagar, & Sapolsky,

1991). In one study, researchers compared handled and nonhandled female rats' spatial memory using the Morris Swim Maze (Meaney, Aitken, et al., 1991). The oldest nonhandled rats exhibited significant spatial memory impairments compared with the youngest nonhandled rats or the same-aged handled rats. Handled animals did not show a significant decrease of neuron density in the brain through mid- and old-age (12 and 24 months) as did nonhandled animals of the same age. Other studies have also demonstrated the protective effects of handling against age-related physiological and neural processes and cognitive impairments (Gabriel, Johnston, & Weinberg, 2002; Meaney, Aitken, et al., 1991; Meaney, Mitchell, et al., 1991; Weinberg, Kim, & Yu, 1995).

Variations in maternal care, even within a normal range, also produce differences in cognitive and neural development (Bredy et al., 2001; Meaney, 2001). For example, offspring of high-LG mothers, compared with low-LG mothers, display superior spatial learning or memory in the Morris Swim Maze (Bredy et al.). This may result from differing levels of sensory experience, yielding differing levels of hippocampal synaptic development, which is necessary for cognitive function (Bredy et al.; Liu, Diorio, Day, Francis, & Meaney, 2000).

Novelty-Seeking Behavior and Touch

Touch also plays a role in novelty-seeking behavior. Data collected in a variety of experimental paradigms indicate that handling and maternal contact increase exploration of novel environments (Bodnoff, Suranyi-Cadotte, Quirion, & Meaney, 1987; Caldji, Francis, Sharma, Plotsky, & Meaney, 2000; Campbell & Spear, 1999; Denenberg & Grota, 1964; Denenberg & Morton, 1963; Denenberg, Schell, Karas, & Haltmeyer, 1966; Fernández-Teruel, Escorihuela, Driscoll, Tobeña, & Battig, 1991; Ferré et al., 1995; Levine, 1959; Levine et al., 1967; Weinberg, Krahn, & Levine, 1978; Williams et al., 1975). As in other domains of behavior, handling is more effective at an earlier age in regard to exploration (Levine, 1959). Maternal actions can also influence pups' exploration. Maternal contact can reduce pups' reactions to novel situations (Caldji et al., 1998; Levine & Stanton, 1990; Stanton, Wallstrom, & Levine, 1987), and pups of low LG-ABN mothers show decreased exploration compared with pups of high LG-ABN mothers (Caldji, Diorio, et al., 2000; Caldji et al., 1998).

A number of studies also indicate that human handling as well as maternal contact decrease the latency of consuming novel substances (Bodnoff et al., 1987; Caldji et al., 1998), increase the consumption of a novel substance (Bodnoff et al.; Caldji, Diorio, et al., 2000; Caldji et al., 1998; Gabriel & Weinberg, 2001; Weinberg, Smotherman, & Levine, 1978, 1980), and increase rats' sensitivity to food types (Weinberg, Smotherman, et al., 1978; Weinberg, Smotherman, et al., 1980). In one study, handled rats began eating approximately three times faster than did nonhandled rats (Bodnoff et al.). Other studies show that handling increases the ability of rats to make distinctions between preferred and

nonpreferred substances; handled and nonhandled animals do not differ in their consumption of a saline solution, but handled animals drink significantly more sucrose solution than do nonhandled animals (Weinberg, Smotherman, et al., 1978; Weinberg, Smotherman, et al., 1980).

Some researchers argue that hyponeophagia—the reduced consumption of a novel substance—and the ability to recover from conditioned taste aversion are related (Weinberg, Smotherman, et al., 1978). Research shows that handling reduces both initial and conditioned taste aversions. After previous exposure to lithium chloride (LiCl) paired with a milk solution, both handled and nonhandled animals lowered their consumption of a milk solution that did not contain the LiCl, but handled animals reduced their consumption by only 34%, whereas nonhandled animals consumed 79% less, indicating that handled animals recovered from the initial taste aversion more readily than did the nonhandled animals (Weinberg, Smotherman, et al., 1978).

Touch and the Reduction of Stress

Touch plays a fundamental role in aiding adaptive stress responses in rats. The physiological response to stress-inducing stimuli involves an elaborate physiological system containing many components, none of which could stand alone. However, individual studies often focus on only one aspect of the system (e.g., glucocorticoid receptors). As a result, the following discussion will be broken down into sections by the main components of the stress response system, which will be briefly explained below. It is not our intent to provide a detailed explanation of the stress response in rats nor to describe the consequences of stress, as many previous articles have already done (e.g., Bredy et al., 2001; Kemeny, 2003). Instead, we intend to describe the effects of handling on this neurological system (see Figure 2).

The stress response is regulated in part by the hypothalamic-pituitary-adrenal (HPA) axis, a negative feedback system. When a stressful stimulus occurs, corticotropin-releasing hormone (CRH) is secreted and partially regulated by gamma amino butyric acid/central benzodiazepine ($GABA_A$/CBZ) receptors, causing adrenocorticotropic hormone (ACTH) to be released and begin circulating. ACTH causes adrenal glucocorticoids, including corticosterone, to be released from the adrenal cortex (Ploj et al., 1999). Glucocorticoid receptors (Gr) sense the presense of glucocorticoids in circulation and help to regulate their production. The hippocampus also is believed to be involved with the inhibitory influence of glucocorticoids. The glucocorticoid that has received the most attention by researchers studying the effects of touch on rats is corticosterone. Adrenal ascorbic acid depletion and reactivity are also included in the present article because both are indexes of stress.

Current researchers focus on the hypothesis that early life events, such as human handling or maternal contact, result in decreased stress reactivity and a

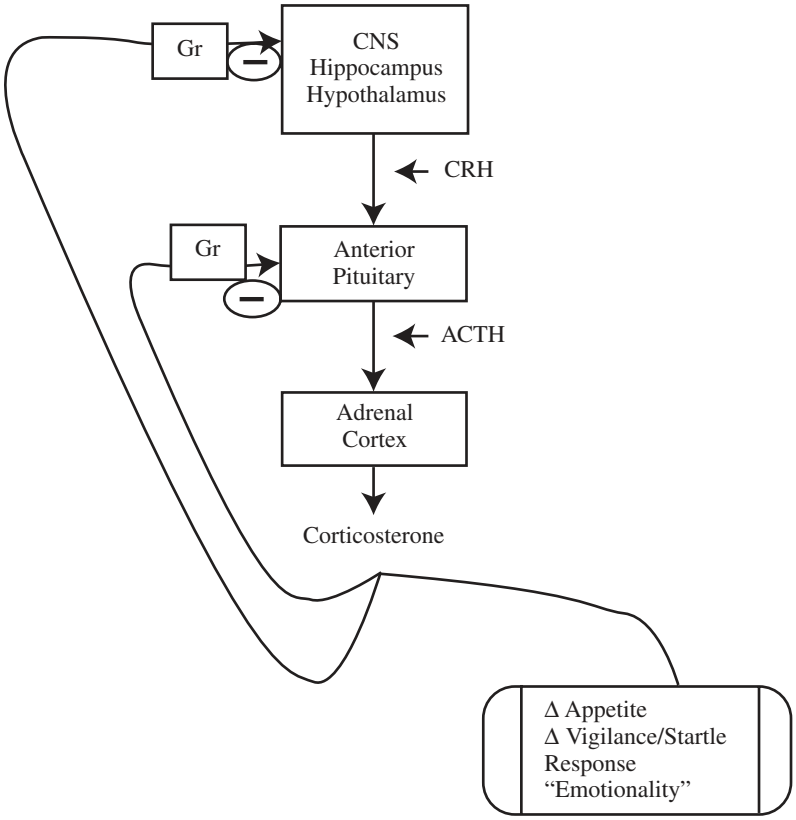

FIGURE 2. Generalized neural pathway for the stress response in rats. CNS = central nervous system. GR = glucocorticoid receptors. ACTH = adrenocorticotropic hormone. CRH = corticotropin releasing hormone.

lowered subsequent vulnerability to stress-induced illness in later life (Meaney, 2001). However, we must acknowledge that these stress responses permit survival during threatening situations. The crucial component here is the time course of the reaction; the immediate rise in the stress response is essential for survival, as is a timely return to basal levels because research indicates that prolonged stress responses render organisms vulnerable to disease (Sapolsky, 2000).

The HPA system. In general, greater activation of the HPA system indicates higher levels of stress, whereas less activation indicates lower levels of stress. The HPA axis is not fully functional through the first 2 weeks of life (Iny, Gi-

anoulakis, Palmour, & Meaney, 1987), but handling leads to more rapid development of the system (Levine, Alpert, & Lewis, 1957). Overwhelming evidence indicates that tactile stimulation via human handling and maternal contact in infancy decreases HPA activity in response to most stressors (Francis & Meaney, 1999; Meaney, 2001; Meaney, Mitchell, et al., 1991; Núñez et al., 1996). Maternal contact decreases HPA activity in response to most stressors both immediately and in adulthood (Bredy et al., 2001; Francis & Meaney, 1999; Levine & Stanton, 1984, 1990; Liu et al., 1997; Meaney; Meaney et al., 1991; Núñez et al.; Pfeifer, Denenberg, & Zarrow, 1973; Stanton et al., 1987; Weinberg, 1987).

CRH, $GABA_A$/CBZ receptors, and ACTH. Tactile stimulation also affects CRH, $GABA_A$/CBZ receptors, and ACTH. CRH is responsible for the initialization of the stress response. Increased maternal touch reduces CRH synthesis even when there are no stress-inducing stimuli present (Caldji, Diorio, et al., 2000; Caldji et al., 1998). Handling also reduces release of CRH after a stressful stimulus (Núñez et al., 1996), indicating that the stress response is modulated. $GABA_A$/CBZ receptors help to regulate central corticotropin-releasing factor (CRF) activity and are also affected by touch. Handling increases the levels of $GABA_A$- and CBZ-receptor binding which may help to modulate the stress response by decreasing CRH signals (Caldji, Francis, et al., 2000; Francis, Caldji, Champagne, Plotsky, & Meaney, 1999; Francis & Meaney, 1999). The effects of handling on ACTH are less straightforward. Levine (1957) found that handling increases ACTH production, and others indicate that ACTH responses are reduced (Gabriel, Yu, Ellis, & Weinberg, 2000; Liu et al., 1997). Perhaps the synthesis of these two different findings is that, although more ACTH may be produced, less may be utilized.

Corticosterone. Handling and maternal touch affect glucocorticoid levels before, during, and after the stress response (Caldji, Diorio, et al., 2000; Denenberg et al., 1967; Meaney, Aitken, et al., 1991). Handling creates a rise in corticosterone in infant pups and is thought to occur because the handling procedure is a stressful stimulus to infant pups (Denenberg et al., 1967; Pfeifer, Rotundo, Myers, & Denenberg, 1976). Multiple studies show that sufficient handling of males and females during early life reduces basal levels of corticosterone throughout the lifespan and decreases corticosterone release following stressful events in adulthood (Ader, 1968; Levine, 1967; Meaney, Aitken, et al., 1991). In one study, for example, nonhandled rats experienced corticosterone levels 50% greater than those of handled rats 30 min following a stressor (Meaney, Aitken, et al., 1991). It is interesting that handling in early life reduces corticosterone release, during stressful events for males, but does not do so for females (Meaney, Aitken, et al., 1991). This sex difference has been attributed to potential sex-dependent effects of handling on pituitary transcortin receptors (Meaney, Aitken, et al., 1991).

Glucocorticoid receptors and negative feedback. Abundant evidence indicates that handling and maternal contact increases glucocorticoid receptor (Gr) expression, leading animals to exhibit adaptive and appropriate responses rather than prolonged responses to stress (Caldji, Diorio, et al., 2000; Liu et al., 1997; Meaney et al., 1985; Meaney, Aitken, Van Berkel, Bhatnagar, & Sapolsky, 1988; Meaney, Mitchell, et al., 1991). In addition, handling appears to increase the rat's sensitivity to the negative feedback from glucocorticoids (Francis & Meaney, 1999; Liu et al., 1997), perhaps because of the increase in receptor sites. Increased sensitivity to glucocorticoids is necessary to inhibit the release of more glucocorticoids, which exacerbates the stress response.

Conclusions. Handling and maternal touch produce animals with a more adaptive stress response, reducing the likelihood of impaired cognitive ability as well as other stress-related diseases (Meaney, Aitken, et al., 1991; Weinberg, 1987). Handled animals show faster initial responses to stress, shorter durations of the stress response, and more appropriate levels of corticosterone, which allow the animal to react adaptively and then return to resting levels (Levine, 1960). Consequently, handled rats cope better in stressful situations (Weinberg & Levine, 1977) and are less susceptible to chronic stress (Meaney, 2001; Núñez et al., 1996).

Attachment and Touch

We have not yet discussed attachment in the traditional sense, and some researchers would argue against doing so (Levine & Stanton, 1984), but many behaviors and physiological phenomena are related to attachment (e.g., emotionality, learning, memory, novelty-seeking behavior, stress, and maternal separation). For example, tactile stimulation from pups alone can induce typical maternal behavior such as grooming from both male and virgin female rats after several days of cohabitation (Stern, 1996). However, stronger effects of tactile stimulation from pups are felt by the mother. Although we discussed these and other phenomena in regard to other aspects of behavior and physiology, they also weigh heavily on attachment.

For over 3 decades, Hofer and his colleagues have studied the attachment system in rats (e.g., Hofer, 1995; Hofer & Shair, 1980). Like humans and nonhuman primates, rat pups display attachment behaviors in response to maternal separation such as ultrasonic separation cries, searching, following, and huddling (Hofer). Furthermore, rat attachment appears to be specific; pups prefer their mother to other lactating dams (Hofer).

Hofer (1995) found that a host of components, including touch, warmth, texture, scent, contour, and movement, comprise mother-pup interaction, but contact has been implicated as one of the most important components of interaction that regulate attachment. In a series of elegantly designed studies, Hofer and Shair (1980) examined which of these components of interaction down-regulated pups'

ultrasonic cries and separation behaviors most powerfully after separation. Using artificial surrogates, the experimenters presented each of the modalities listed above to rat pups and found that only texture and thermal warmth, when presented alone, were effective in down-regulating attachment behaviors. Hofer suggested that touch (texture and warmth), independent of other modalities, down-regulates attachment behaviors in rats.

The work of Hofer and his colleagues clearly implicates the importance of touch in the mother-pup relationship in the formation of attachment (Hofer, 1995; Hofer & Shair, 1980; Weinberg, Smotherman, et al., 1978). Touch is a critical component in the effects of separation on the rat. Although rats may not seem like a traditional model for attachment, mother-pup attachment stands as an excellent model. Unlike nonhuman primates, which usually are in contact with their mothers, rat pups endure daily, brief separations that more closely resemble human schedules of contact and separation (Hofer, 1995).

Tactile stimulation affects rats in a number of other domains in addition to those we already discussed. For example, research shows that handled male rats survive longer than do nonhandled male rats following injection with leukemia (Levine, 1962a, 1962b). Touch also plays a role in reversing deficits from prenatal stress, including deficits accrued from prenatal alcohol exposure (Gabriel et al., 2002; Gabriel & Weinberg, 2001; Gabriel et al., 2000; Smythe, McCormick, Rochford, & Meaney, 1994; Wakshlack & Weinstock, 1990; Weinberg & Gallo, 1982; Weinberg et al., 1995). Handling also has the potential to decrease susceptibility to addiction later in life (Campbell & Spear, 1999; Hilakivi-Clarke, Turkka, Lister, & Linnoila, 1991; Weinberg, 1987) and is known to attenuate learned helplessness (Costela et al., 1995; Tejedor-Real et al., 1998).

Summary and Conclusions

Clearly, the effects of tactile stimulation on rats are prominent and pervasive. Many insights toward the physiology of touch can be gleaned from research done with rats, and results should cautiously be extrapolated to other species. Touch has positive consequences for the developing rat pup and influences emotionality, learning, memory, novelty-seeking behavior, stress, and forming attachments. Perhaps the most important area of future research is on the biological mechanisms that underpin the behavioral consequences of touch (Verbalis, McHale, Gardiner, & Stricker, 1986). This would be of great benefit because knowledge of underlying processes could more readily be generalized to other species.

FINAL CONCLUSIONS

In the current article, we have reviewed the communicative functions of touch in humans, nonhuman primates, and rats. Although touch has been rele-

gated by researchers as a domain of study, there is certainly enough empirical literature to indicate that touch plays an important role for humans, nonhuman primates, and rats. Several functions cut across these populations including the role of touch in stress, status, emotion, and what one might call an *affiliation function among conspecifics* (i.e., attachment, bonding, intimacy, and liking).

Throughout this review, we pointed out specific limitations of and gaps in the empirical data. However, the body of literature, or at least parts of it, suffer from some more general problems. First, there is a clear need to construct reliable coding systems to investigate the qualities and parameters of tactile stimulation; although researchers studying adults and infants have devised coding systems (e.g., Weiss, 1992), few coding systems have been published to code nonhuman primate or rat touch. Constructing, publishing, and employing common coding systems (even within species) to examine tactile interactions would have two effects. First, researchers would be better able to compare the results of investigations. Second, systems that would code the qualities of touch would encourage researchers to code this facet of touch. Typically, investigators in all three domains of literature code the frequency of touch and ignore the quality of touch, or at least code quality of touch in a gross manner. Having a reliable system to code the quality and quantity of touch would encourage researchers to include them.

Second, a related issue is that researchers studying touch tend not to employ coding systems that recognize the dyadic, dynamic, and contingent nature of tactile interaction. Instead, researchers code tactile interaction that is conceptualized in a unidirectional framework (e.g., Hertenstein & Campos, 2001). It is interesting that coding systems that recognize the bidirectional nature of communication are already available, although they do not explicitly code for tactile communication (Hsu & Fogel, 2003; Tronick & Cohn, 1989). Our knowledge of tactile communication would be greatly enhanced by adopting coding systems that recognize the dynamic and bidirectional nature of touch.

Third, there is a clear need in the literature for converging research operations so we can be more confident in the inferences that we draw about the communicative functions of touch. In many cases, only one research design (e.g., observation) or sample (e.g., college students) is employed. For example, in the study of power or status in adults, researchers use observation in the vast majority of the investigations. Employing more experimentally rigorous studies that manipulate power (rather than examining the effects of gender) may be very illuminating and allow researchers to make inferences more confidently.

Fourth, researchers must be ever mindful of the fact that tactile communication takes place amongst other modalities of communication and in a larger context. Researchers who study touch must balance the need to understand the role of touch in its own right versus the fact that touch takes place in a broader context. This context includes not only stimulation from other modalities, but also the immediate ecological context as well as the larger societal context (Bronfenbrenner & Morris, 1998).

Finally, the literature that we reviewed has a clear positivity bias. With the exception of the tactile deprivation literature, researchers tend to study the positive aspects of touch (stress reduction, attachment, bonding), to the detriment of the negative effects of touch (Major, 1981). The reasons for this positivity bias may stem from ethical considerations, particularly when studying humans. Nevertheless, touch certainly communicates negative emotions and stimulates nociceptive nerves, yielding enduring consequences. Focus on the more negative consequences of tactile communication is clearly warranted.

The field of tactile communication is still in an embryonic state and has yet to develop into a coherent and systematic field of inquiry. It is ironic that touch may well represent one of the most powerful modalities of communication in humans, nonhuman primates, and rats, yet it is one of the least understood means of communication. We hope that our review will serve the field by synthesizing the communicative functions of touch and will provide an impetus to further the study of touch across a variety of disciplines and levels of analysis.

NOTES

1. This search was conducted on February 28, 2006.
2. *Touch* primarily refers to cutaneous processes, but kinesthetic processes are involved as well because they are difficult to separate from one another. Together, cutaneous and kinesthetic processes comprise the somaesthetic sense.
3. Note that we do not focus on *active touch* or what some call *haptic perception*.
4. In this section, we draw heavily from some of our other writings, which discuss some of these same issues.
5. These behaviors are characteristic of infants classified as disorganized or disoriented in the Strange Situation (Main, personal communication, April 11, 2002).
6. We are concerned with the effects of tactile stimulation. Because grooming involves tactile stimulation, we use the terms interchangeably. However, we realize that the term *grooming* is sometimes used only in reference to highly ritualized behavior.

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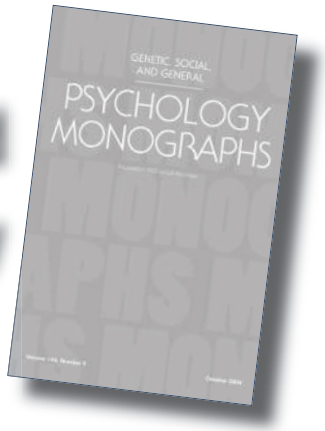

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