Chapter 14
Social Touch

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Abstract The more social aspects of touch, despite their relevance to numerous domains of human behavior, from cultural anthropology to cognitive neuroscience, and from virtual reality through to linguistics, have not been extensively studied by scientists. That is, psychologists and neuroscientists are only now beginning to uncover some of the neurocognitive mechanisms responsible for these important real-world interactions. In this chapter, we summarize the latest developments in this field of research. In particular, we highlight a number of studies where touch, no matter whether direct or mediated by technological devices, has been shown to affect our behavior, as well as our physiological reactions. We show how this sensory modality often acts as a powerful interface allowing us to interact socially and emotionally with the world around us. The available research also suggests that touch plays an important role in supporting our well-being.

Keywords Touch • Interpersonal • Well-being • Neuroscience • Technology • Social

Introduction

It takes nothing more than a caress, be it tender or erotic, to remind us of the importance of social touch to our everyday lives. That said, experimental psychologists and cognitive neuroscientists are only now beginning to uncover some of the cognitive and neural mechanisms underpinning this most important aspect of our behavior. Surprisingly, however, this increased scientific interest in the study of the more social aspects of touch has been paralleled by a global trend toward there being less social touch in our everyday public interactions. Indeed, it has long been suggested

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that many industrialized societies are drifting toward a state of 'touch hunger' (see Field 2001), where tactile interactions are limited and often actively inhibited or even prohibited (for fear of harassment claims or litigation).

The study of the more social aspects of touch is relevant to many different disciplines, including cultural anthropology, social psychology, physiology, the neurosciences, and linguistics among many others. Given such a complex array of relevant research fields, and the fact that a truly interdisciplinary approach to the study of touch still has not been fully developed, it is not so surprising to observe that social touch has received far less attention than the study of many other topics in psychology. Moreover, it should also be borne in mind that touch is actually one of the least well studied of the senses (especially if one compares it with the far greater number of studies that have been conducted on vision and audition; see Gallace and Spence 2014, for a review). Even today, it would seem as though many of the same factors that have prevented us from increasing the incidence of tactile social interactions in public social situations have also been responsible, at least in part, for the slow rate of progress of academic research in this field. That is, asking people to touch each other in order to study the neurocognitive mechanisms underpinning tactile social processing can be seen to be a rather delicate matter, at least from an ethical standpoint (not to mention the limited ecological validity of a study where people are not free to touch or be touched by whomever they want). Surprisingly, however, there are perhaps more studies on the topic of sexual behavior than there are on the topic of public social touch. Moreover, even within the tactile modality itself, there has been far more research on the sensory/discriminative properties of touch, than on the more social/hedonic properties (see Gallace and Spence 2010, 2014; Kitada et al. 2010a, b).

The possibility of using machines that are capable of reproducing, at least electromechanically, certain patterns of tactile stimulation across the surface of the human skin has certainly provided a promising starting point for the development of this field of research (e.g., Essick et al. 2010). Note, however, that while we are now, at least in principle, able to simulate certain kinds of tactile sensation successfully (e.g., the amount of pressure, the speed, etc.), our knowledge on this topic is still far from sufficient when it comes to knowing what cues need to be provided or what exactly should be simulated and how, in order to deliver certain specific sensations. At the moment, it is not even clear whether certain kinds of tactile stimulation can exert the same effects within a social context when reproduced mechanically/digitally (e.g., Haans et al. 2007; Haans and IJsselsteijn 2006; Haans et al. 2008; see also Gallace and Spence 2010, 2014 for reviews).

Over the last few decades, many studies have addressed the cognitive and neural correlates of tactile information processing (see Gallace 2012; Gallace and Spence 2014; Hertenstein and Weiss 2011, for reviews), demonstrating that touch and the skin provide an important means of differentiating ourselves from the external world. Where touch begins we are, one might say. However, touch not only provides a protective function (together with the pain system) by informing us about potentially dangerous stimuli, it also acts as a powerful interface that allows us to interact socially with the world at large. In this chapter, we will examine how this occurs and what the putative mechanisms are that allow us to interpret, at least from a social point of view, those signals impinging upon the body surface.

Social Touch from Birth (and Earlier) Through to Old Age

Touch is the first sense to develop within the womb (e.g., Montagu 1978). In fact, a 6-week-old embryo can already perceive and respond to various tactile stimuli (e.g., Atkinson and Braddick 1982; Bremner et al. 2012). This early development is especially impressive if one considers the fact that many more weeks of maturation are required before the other senses really start to develop. Early tactile interactions have also been reported to occur between twin fetuses in the womb itself (Castiello et al. 2010). In fact, Castiello and his colleagues documented the occurrence of movements aimed at touching the co-twin starting from the 14th week of gestation. Even after birth, when the newborn's sight is still very poor (e.g., Atkinson and Braddick 1982), touch offers the very first means of contact and interaction with the outside world. The very first examples of pleasant and comforting sensations in our life are mediated by touch. Given that the human baby is, from a functional and anatomical point of view, critically undeveloped with respect to other mammals (and thus requires a much higher level of parental care), it is natural that these early forms of interaction must be social in nature. The automatic hand closure response seen in babies in response to those objects that are placed in their palm is certainly an important mechanism for helping the developing newborn to determine the nature of external stimuli. However, the fact that this behavior can also be observed when the feet of a newborn baby is touched (e.g., Zappella 1967) would seem to suggest a somewhat different evolutionary role: That is, this behavior might also carry an important social function. In fact, baby primates use this automatic grasping behavior in order to cling on to their mother's fur. Thus, maintaining the physical contact with the caregiver (and the level of comfort mediated by that) can probably be seen as one of the most important functions in the early stages of human development.

The possible importance of touch in human babies has been hinted at by a series of controversial studies conducted by Harry Harlow (e.g., Harlow 1958; Harlow and Zimmerman 1959). Harlow and his team removed baby rhesus monkeys from their mothers, and assigned them to a couple of surrogate mothers, one made of terrycloth (that did not provide any food) and the other, of metal wire, that did provide sustenance. He observed that the baby monkeys spent the majority of their time on the terrycloth mother, even though it didn't provide them with any nourishment. Moreover, those baby monkeys who were assigned to wire-only mothers suffered from diarrhea more often, and what is more, had more trouble digesting their milk. On the basis of these results, Harlow went on to conclude that the lack of social tactile contact is extremely stressful, at least for this mammalian species (but, by extension, for others too). Even if one ignores the oft-cited ethical concerns related to this study, whether or not its results can be extended to humans remains rather unclear (see also Edelmann et al. 2013, for a recent study on the role of maternal touch on the juvenile social play behavior of rodents).

Different studies have attempted to investigate the role of early tactile deprivation on different biological, cognitive, and social functions. It is important to note here that regardless of the results obtained, all of this research has tended to concentrate on

those unfortunate children who have had to live for some period of time in orphanages that were deemed to have provided a very substandard level of care. As a consequence, it is impossible to determine whether any difference between these children and those who had been raised in a more standard and socially rich environment might have been due to the lack of tactile contact, or rather, to the more general sensory, social, and cognitive deprivation that they suffered. Therefore, on the basis of these studies, no scientific conclusions can be drawn regarding the importance of early tactile interactions on the cognitive and social development of humans.

Evidence regarding the importance of tactile contact at an early stage of life in humans comes from the study of the 'kangaroo care method.' This technique is commonly used in developing countries. The method was developed back in the 1970s by one Dr. Edgar Rey Sanabria in Bogotà, Colombia, in order to address a shortage of incubators and medical personnel and it mainly consists of maintaining skin-to-skin contact between the newborn baby and the mother or father (see Rodgers 2013, for a recent review). Even if its initial purpose was to provide warmth, nutrition, and to enhance the likelihood of an early hospital discharge for low-birth-weight babies, further research studies have demonstrated that it results in improved neonatal signs in terms of heart rate, respiratory rate, sleep, pain relief, and neurobehavioral general development (e.g., Ludington-Hoe et al. 2008). That is, early tactile social contact seems to provide a very important role in the normal functioning of the organism during the earliest stages of human development.

Interestingly, tactile social contact is not only relevant at this point in human development, but throughout the lifespan, that is, from childhood through to old age (Field 2001). For example, it has been suggested that in adults social touch may contribute to the maintenance of longer lasting relationships (probably due to its effect on oxytocin release; see the section below; e.g., Gulledge et al. 2007; Holt-Lunstad et al. 2008). Tactile stimulation also seems particularly relevant to the growing aging population, who often complain about the fact that fewer and fewer people want to touch them as they become old and wrinkly (note how this contrasts with the desire to touch the skin/cheeks of new born babies; e.g., see Field 2001). So, for example, one study reported by Eaton et al. (1986) hints at the important role that social tactile contact might play in improving the condition of institutionalized elderly individuals. They found that when the service staff who were caring for these patients combined their verbal encouragement to eat with tactile contact, the individuals concerned consumed significantly more calories and protein.

Social Touch at Work

It has been demonstrated that tactile social interactions, even if they go unnoticed (or else are not particularly relevant to the context in which they occur), can exert a very powerful effect in a person's evaluation of a given situation, or else in eliciting certain kinds of behavior. For example, people become more

compliant with requests when they are touched by another person than when they are not touched (this phenomenon is known as the 'Midas touch effect'; e.g., Crusco and Wetzel 1984). However, within certain contexts, touch can obviously also have negative consequences on our behavior or judgments. So, for example, Martin (2012) reported that those individuals who were touched by another customer when examining the merchandize in a store evaluated the products more negatively than did those customers who weren't touched. That is, the context in which touch takes place can have a powerful effect on the evaluation of the tactile stimulation itself (Gallace and Spence 2014). Interestingly, this seems to apply both to the more perceptual and to the more social aspects of touch (see McCabe et al. 2008; for an elegant study showing how the affective experience of touch and the sight of touch can be modulated by higher order cognitive evaluations).

The role of context (e.g., where the touch originates from) in affecting the perception of social touch has been highlighted by an intriguing study by Gazzola and her colleagues. These researchers delivered the same pattern of tactile stimulation, consisting of a series of caresses administered to the shin and calf to a group of male participants while they viewed different visual displays (Gazzola et al. 2012). In particular, the participants were told that the touch was administered by the person that they could see in the video. In one condition, the video portrayed an attractive woman wearing a black evening dress and high heels, while, in the other, a man was shown wearing a black tank top and jeans. These researchers reported that not only was the tactile stimulation perceived differently (in term of its pleasantness) as a function of the context in which it appeared to have been presented, but that even the activity of one of the brain areas involved in the early processing of tactile information (i.e., the somatosensory cortex) was modulated by these higher order cognitive factors.

The observations reported in this section clearly highlight the important role that social touch can play in driving human behavior, whether we realize it or not. However, by analyzing these studies one cannot fail to notice that when attempting to study the topic of social touch, researchers need to move from more laboratory-based situations to more ecologically valid contexts. From a scientific point of view, this certainly becomes problematic. In fact, more ecologically valid situations are obviously going to lack the control over a number of important variables that might well be expected to affect one's results (such stimulus control can obviously be more easily guaranteed in the case of laboratory-based experiments). At the same time, one can only wonder about how a very controlled laboratory study, such as one in which the participant has to lie completely still and immobilized in a fMRI scanner (with their head clamped still), while a stranger touches them, can be considered as somehow being similar to any real life tactile social interaction (see also Komisaruk et al. 2004; Mallick et al. 2007; for examples of studies on human sexual behavior conducted in the fMRI scanner).

The Neural Basis of Social Touch

Despite of the fact that many different studies have investigated the neural basis of tactile sensory processing, a surprisingly small number of researchers have actually addressed the neural mechanisms underlying our perception of the more social aspects of touch. In one of the few examples of this kind of research, Schaefer et al. (2013), analyzed, by means of fMRI, the responses of the primary somatosensory cortex (S1) of their participants while they watched video clips showing simple nonpainful tactile stimulation being delivered to another person's hand. These researchers reported that a part of this brain area, one that generally responds to the tactile stimulation delivered to the participant's own body, would actually also respond to the observation of touch being delivered to another person (see also Blakemore et al. 2005; Bolognini et al. 2012; McCabe et al. 2008, for similar results). Previous studies have demonstrated that, in certain individuals, such neural activation can also give rise to a conscious perception of touch on their own body, a phenomenon known as mirror-touch synesthesia (see Blakemore et al. 2005; though see also Deroy and Spence, in press). Here, though, it should be noted that it remains somehow unclear whether the activation of S1 observed by Schafer and his colleagues was related to a 'social neural mirror system' that responds to the tactile stimulation seen occurring to another individual, or whether instead it may merely reflect the mental imagination of the effects that the touch seen on the screen might have on a participant's body (Spence and Deroy 2013). In fact, in a previous study, the same research team documented a correlation between the personality dimension of 'perspective taking' (the extent to which someone cognitively imagines a situation from the other person's point of view; e.g., Furlanetto et al. 2014) and the activation of S1 due to the sight of tactile contact (Schaefer et al. 2012).

Interestingly, Schaefer and his colleagues (2013) in their study also found that the observation of touch resulted in activation in the insular cortex, a part of the brain that is involved in self-awareness. That is, it would seem as though when people watch tactile stimulation in others the systems involved in differentiating the self from other needs to be actively maintained. Taken together, then, these results would seem to suggest the presence of an important link between the neural systems that are responsible for the processing of tactile information and those supporting the difference between self and others, a critical function at the basis of any social interaction (e.g., Moseley et al. 2012).

Indirect evidence on the role of social touch on neural processing comes from a study by Teneggi et al. (2013). Following on from the observation that a sound can affect tactile processing when presented within peripersonal space, these authors asked their participants to detect a tactile stimulus that was presented on their face while concurrent task-irrelevant sounds were heard to approach toward or recede from their face. They then calculated the critical distance at which auditory stimuli speeded up the participants' tactile reaction times (RTs) and considered this distance to be the boundary of peripersonal space. Taneggi et al. found that peripersonal space is modulated (i.e., shrinks) when another individual faces the participant. These results would therefore seem to suggest that social factors affect the functioning of

neural systems that are responsible for maintaining a representation of a person's peripersonal space (see also Graziano and Cooke 2006; Spence 2011).

One of the most promising fields of investigation within research on social touch is likely going to be related to the relatively recent discovery of a new class of tactile fibers in humans, known as C-Tactile (CT) afferents(e.g., see Löken et al. 2009; McGlone and Spence 2010). These fibers, which are found in the hairy, but not in the glabrous skin, respond optimally when the skin is stroked at a speed of about 1–10 cm/s, a stimulation that can resemble a caress (e.g., Bessou et al. 1971; Iggo 1960; Olausson et al. 2008). These fibers would seem to be associated with the perception of the more pleasant aspects of tactile stimulation. It has even been suggested that the C-Tactile fibers constitute part of a neural system responsible for the maintenance of physical and social well-being in humans (e.g., Björnsdotter et al. 2010; Morrison et al. 2009; see also Cascio et al. 2012; Marco et al. 2012; McGlone et al. 2007, for the possible link between tactile processing and autism—a disorder including abnormalities of social behavior—in humans). Interestingly, it has been shown that a reduction in the density of thin and unmyelinated nerve fibers, including the C afferents, can result in a perceived reduction in the pleasantness of tactile stimulation (Morrison et al. 2011b). Moreover, the patients affected by this lack of neural fibers rate tactile stimuli seen in short videos depicting the stroking of on another person's forearm as less pleasant.

The presence of the CT fibers in humans, and their apparent involvement in the perception of the more pleasant aspects of our behavior, certainly provides some evidence concerning the importance of affiliative social interactions in the tactile modality. This crucial role of tactile interactions in our social behavior is also supported by a number of studies that have been conducted on couples. It has been reported that those women who received physical contact from their partners before a stressful situation exhibit significantly lower cortisol and heart rate responses to stress (e.g., Ditzen et al. 2007). As far as the areas of the brain responsible for the processing of the signals resulting from the activation of CT afferents is concerned, a recent study by Gordon et al. (2013) has shown that the gentle stroking of the arm as compared to the stroking of the palm of the hand (an area of the body that isn't innervated by CT afferents) resulted in the activation of the posterior insula, as well as a network of areas that are known to be involved in social perception and social cognition (comprising the right posterior superior temporal sulcus, the medial prefrontal cortex, and the dorsoanterior cingulate cortex; see also McGlone et al. 2012; Morrison et al. 2011a).

Here, it is important to note that many effects of social touch on behavior and physiological responses are likely mediated by hormonal mechanisms. In fact, it has been demonstrated that tactile stimulation, be it of a sexual or nonsexual nature, induces the release of oxytocin (e.g., Shermer 2004; Williams et al. 1992), a hormone that has been implicated in human and animal bonding behavior (e.g., Bales and Carter 2003; Schneiderman et al. 2012). This hormone is also informally known as the 'cuddle hormone' (e.g., http://news.bbc.co.uk/2/hi/health/8653500.stm downloaded on 06/08/2013). Interestingly, the relationship between tactile processing and hormone release would appear to be a two-way one. That is, tactile sensations certainly affect the release of hormones, but the perception of touch can also be affected by hormone release. So, for example, during the refractory period (this is the name given to the period of time immediately following orgasm) males expe-

rience tactile hypersensitivity in the glans of the penis (Yilmaz and Aksu 2000; see also Humphries and Cioe 2009, for the report of a similar phenomenon in some women). This sudden change in sensitivity results in tactile stimuli applied to this region being perceived as highly aversive and seems to be related to the localized release of prolactin following orgasm (Krüger et al. 2003). Prolactin is sometimes referred to as the 'paternity hormone,' and its release seems to play an important role in limiting and controlling human sexual behavior.

The Development of Mediated Social Touch for the 'Internet Generation'

Many of our daily activities, such as buying groceries or consulting a library archive can be now performed from the comfort of our desk or sofa, that is, without the need to leave our own homes. The rapid growth of the internet has certainly changed our lives in many ways and especially our way to communicate with other people. There is nothing like a Tweet or a post on one's Facebook profile to spread the news about one's latest holiday exploits or even about a recent trip to the doctors. In fact, there isn't a single aspect of our life that cannot be shared with friends or strangers with the click of a mouse. That is, social media allow our thoughts to reach an incredible number of people more quickly than ever before (see Spies and Margolin 2014, for a discussion on the diffusion of social media among adolescents). Researchers have even shown that the use of the internet may be beneficial for reducing loneliness and increasing social contact among older adults in assisted and independent living communities (e.g., Cotton et al. 2013; Park et al. 2013). It should come as little surprise, then, that different kinds of media allow for the emergence of very different kinds of social interaction. Some of these interactions, such as, for example, internet chats, are limited to written contents. In this case, the lack, or insufficiency of the social context for interpreting certain expressions, has somehow been fixed by means of simple symbols that can immediately add some social or emotional meaning to a sentence, namely, the 'emoticons' (e.g., Ganster et al. 2012).

Other forms of internet-based communication provide the possibility of communicating by means of a virtual counterpart of our body, what is called an 'avatar.' This is the case for software such as 'Second Life,' where an individual can control his/her own customized avatar and use it in order to perform actions and communicate with other people's avatars within the context of a virtual world (e.g., Wagner 2008; see also Ward 2007). Despite the big improvement that the latter forms of interactions would seem to provide (they may offer the possibility of expressing ourselves by means of a virtual counterpart to our actual body), watching a mannequin shaking hands, nudging, or even making love with another mannequin is certainly far from what can be called a realistic and rewarding social interaction. That is, tactile contact is so far lacking in all forms of internet-based communication, comprising those occurring within virtual worlds.

Importantly, some attempts to fill this gap have started to emerge over the last decade. One example of a device that has been developed to provide mediated

social touch is certainly the hug-shirt. More recently, an internet-connected jacket, named "Like-A-Hug," which inflates to give the wearer a hug every time a Facebook friend "likes" a status update or photo has been developed (see http://www.huffingtonpost.com/2012/10/15/like-a-hug-jacket-embrace_n_1942421.html downloaded on the 08/08/2013).

As one can easily imagine, none of these devices has yet spread over a large section of everyday internet users. Most of them actually never hit the market and can only been described as advanced prototypes or perhaps as engineering case studies. The lack of appeal of these devices is probably not only due to their inadequacy in terms of delivering believable tactile social interactions, or to the fact that they fail to capture some fundamental aspects of social touch, but also to their inability to reproduce a multisensory context that is congruent with the large majority of our social interactions. That is, holding a mouse (even if it vibrates when someone else wants to communicate with us; see Gallace et al. 2007) is most likely going to activate our brain's memory networks related to PC working activities rather than memory traces related to embracing or caressing a spouse or partner.

Perhaps the only systems that have witnessed some form of success among the WWW population are those known as 'teledildonics.' These are electronic sex toys that can be controlled by a computer and allow physical tactile sexual stimulation to be transmitted over a distance (e.g., Machulis 2006; see also Bardzell and Bardzell 2011). However, the success of these devices is perhaps attributable more to their ability to create new forms of mediated sexual interactions than to their ability to reproduce all of those sensations that can be experienced during real intimate contacts. Think about one of the classic scenes in erotic literature or movies, the use of an ice cube to arouse someone (a scene that also appeared in the 2015 controversial but very popular movie '50 Shades of Grey'). Despite its clear power, to date no technology can so far allow to reproduce something similar to that. Even more importantly, the mechanisms eliciting such strong sensations are far from being fully understood by researchers. In fact, the majority of the teledildonics devices that have been developed so far limit the delivery of tactile stimulation to the genital regions. It should, however, be said that the stimulation reproduced by these devices is now more than ever before based on the results of those studies that analyzed the tactile innervation of the genitals and the neural responses to their stimulation.

Conclusions

As this brief review of the literature will hopefully have made clear, the area of social touch is important, albeit understudied, and what is more it plays a crucial role from long before our birth through to our last moments on planet earth. Researchers are still making many exciting discoveries regarding this understudied sense, be it CT afferent fibers, or the relationship between tactile contact and the release of hormones. These discoveries are now becoming increasingly important due to the diffusion of internet-based social media. In fact, most of these new means of communication

do not (at the moment at least) allow for the occurrence of tactile contact, with potentially important effects on our social relationships and even on our well-being. In order for significant progress to be made, a multidisciplinary approach will be extremely important within this field of research in the years to come.

References

Atkinson J, Braddick O (1982) Sensory and perceptual capacities of the neonate. In: Stratton P (ed) Psychobiology of the human newborn. John Wiley, London, pp 191–220

Bales KL, & Carter CS (2003). Sex differences and developmental effects of oxytocin on aggression and social behavior in prairie voles (Microtus ochrogaster). Horm Behav 44:178–184

Bardzell J, Bardzell S (2011) "Pleasure is your birthright": digitally enabled designer sex toys as a case of third-wave HCI. In: Proceedings of the International Conference on Human Factors in Computing Systems, CHI2011

Bessou P, Burgess PR, Perl ER, & Taylor CB (1971) Dynamic properties of mechanoreceptors with unmyelinated (C) fibers. J Neuropsychol 34:116–131

Björnsdotter M, Morrison I, & Olausson H (2010). Feeling good: On the role of C fiber mediated touch in interoception. Exp Brain Res 207:149–155

Blakemore S-J, Bristow D, Bird G, Frith C, Ward J (2005) Somatosensory activations during the observation of touch and a case of vision-touch synaesthesia. Brain 128:1571–1583

Bolognini N, Olgiati E, Xaiz A, Posteraro L, Ferraro F, Maravita A (2012) Touch to see: neuropsychological evidence of a sensory mirror system for touch. Cereb Cortex 24:276–286

Bremner A, Lewkowicz D, Spence C (eds) (2012) Multisensory development. Oxford University Press, Oxford

Cascio C, Moana-Filho E, Guest S, Nebel MB, Weisner J, Baranek G, Essick G (2012) Perceptual and neural response to affective tactile texture stimulation in adults with Autism Spectrum Disorders. Autism Res 5:231–244

Castiello U, Becchio C, Zoia S, Nelini C, Sartori L, Blason L, D'Ottavio G, Bulgheroni M, Gallese V (2010) Wired to be social: the ontogeny of human interaction. PLoS One 5(10):e13199

Cotton SR, Anderson WA, McCullough BM (2013) Impact of internet use on loneliness and contact with others among older adults: cross-sectional analysis. J Med Internet Res 15:e39

Crusco AH, & Wetzel CG (1984). The Midas touch: The effects of interpersonal touch on restaurant tipping. Pers Soc Psychol Bull 10:512–517

Deroy O, Spence C. Synaesthesia reclassified: borderline cases of crossmodally-induced experiences. In: Deroy O (ed) Sensory blending: new essays on synaesthesia. Oxford University Press, Oxford (in press)

Ditzen B, Neumman I, Bodenmann G, vonDawans B, Turner RA, Ehlert U, & Heinrichs M (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. Psychoneuroendocrinology, 32, 565–574

Eaton M, Mitchell-Bonair IL, Friedmann E (1986) The effect of touch on nutritional intake of chronic organic brain syndrome patients. J Gerontol 41:611–616

Edelmann MN, Demers CH, & Auger AP (2013). Maternal touch moderates sex differences in juvenile social play behavior. PLoS ONE, 8(2): e57396. doi:10.1371/journal.pone.0057396

Essick GK, McGlone F, Dancer C, Fabricant D, Ragin Y, Phillips N, Jones T, Guest S (2010) Quantitative assessment of pleasant touch. Neurosci Biobehav Rev 34:192–203

Field T (2001) Touch. MIT Press, Cambridge, MA

Furlanetto T, Gallace A, Ansuini C, Becchio C (2014) Effects of arm crossing on spatial perspective taking. PLoS One 9(4):e95748

Gallace A (2012) Living with touch: understanding tactile interactions. Psychologist 25:3–5

Gallace A, Spence C (2010) The science of interpersonal touch: an overview. Neurosci Biobehav Rev 34:246–259

Gallace A, Spence C (2014) In touch with the future: the sense of touch from cognitive neuroscience to virtual reality. Oxford University Press, Oxford, UK
Gallace A, Tan HZ, Spence C (2007) The body surface as a communication system: the state of the art after 50 years. Presence Teleop Virt 16:655–676
Ganster T, Eimler SC, Krämer NC (2012) Same same but different!? The differential influence of smiles and emoticons on person perception. Cyberpsychol Behav Soc Netw 15:226–230
Gazzola V, Spezio ML, Etzel JA, Castelli F, Adolphs R, & Keysers C (2012). Primary somatosensory cortex discriminates affective significance in social touch. Proc Natl Acad Sci U S A 109:E1657–666
Gordon I, Voos AC, Bennett RH, Bolling DZ, Pelphrey KA, Kaiser MD (2013) Brain mechanisms for processing affective touch. Hum Brain Mapp 34:914–922
Graziano MS, Cooke DF (2006) Parieto-frontal interactions, personal space, and defensive behavior. Neuropsychologia 44:845–859
Gulledge AK, Hill M, Lister Z, Sallion C (2007) Non-erotic physical affection: it's good for you. In: L'Abate L (ed) Low-cost interventions to promote physical and mental health: theory, research, and practice. Springer, New York, pp 371–383
Haans A, IJsselsteijn W (2006) Mediated social touch: a review of current research and future directions. Virt Real 9:149–159
Haans A, de Nood C, IJsselsteijn W (2007) Investigating response similarities between real and mediated social touch: a first test. In: CHI Extended Abstracts 2007, pp 2405–2410
Haans A, IJsselsteijn WA, Graus MP, Salminen JA (2008) The virtual Midas touch: helping behavior after a mediated social touch. In: Extended abstracts of CHI 2008. ACM Press, New York, pp 3507–3512
Harlow HF (1958). The nature of love. Am Psychol 13:673–685
Harlow HF, & Zimmerman RR (1959). Affectional responses in the infant monkey. Science 130: 421–432
Hertenstein M, Weiss S (eds) (2011) The handbook of touch. Springer, Berlin
Holt-Lunstad J, Birmingham WA, Light KC (2008) Influence of a "warm touch" support enhancement intervention among married couples on ambulatory blood pressure, oxytocin, alpha amylase, and cortisol. Psychosom Med 70:976–985
Humphries AK, Cioe J (2009) Reconsidering the refractory period: an exploratory study of women's post-orgasmic experiences. Can J Hum Sex 18(3):127–134
Iggo A (1960). Cutaneous mechanoreceptors with afferent C fibres. J Physiol 152:337–353
Kitada R, Dijkerman C, Soo G, Lederman SJ (2010a) Representing human hands haptically or visually from first- vs. third-person perspectives. Perception 39:236–254
Kitada R, Johnsrude IS, Kochiyama T, Lederman SJ (2010b) Brain networks involved in haptic and visual identification of facial expressions of emotion: an fMRI study. Neuroimage 49:1677–1689
Komisaruk BR, Whipple B, Crawford A, Liu WC, Kalnin A, Mosier K (2004) Brain activation during vaginocervical self-stimulation and orgasm in women with complete spinal cord injury: fMRI evidence of mediation by the vagus nerves. Brain Res 1024:77–88
Krüger TH, Haake P, Haverkamp J, Krämer M, Exton MS, Saller B, Leygraf N, Hartmann U, & Schedlowski M (2003). Effects of acute prolactin manipulation on sexual drive and function in males. Journal of Endocrinology, 179, 357–365
Löken LS, Wessberg J, Morrison I, McGlone F, & Olausson H (2009). Coding of pleasant touch by unmyelinated afferents in humans. Nat Neurosci 12(5):547–548
Ludington-Hoe SM, Morgan K, Abouefettoh A (2008) A clinical guideline for implementation of kangaroo care with premature infants of 30 weeks' postmenstrual age. Adv Neonatal Care 8:S3–S23
Machulis K (2006) An open-source sexual HCI research platform. In: CHI 2006, April 22–27, Montreal, Canada
Mallick HN, Tandon S, Jagannathan NR, Gulia KK, Kumar VM (2007) Brain areas activated after ejaculation in healthy young human subjects. Indian J Physiol Pharmacol 51:81–85
Marco EJ, Khatibi K, Hill SS, Siegel B, Arroyo MS, Dowling AF, Neuhaus JM, Sherr EH, Hinkley LN, Nagarajan SS (2012) Children with autism show reduced somatosensory response: an MEG study. Autism Res 5:340–351

Martin BAS (2012) A stranger's touch: effects of accidental interpersonal touch on consumer evaluations and shopping time. J Consum Res 39:174–184
McCabe C, Rolls ET, Bilderbeck A, McGlone FP (2008) Cognitive influences on the affective representation of touch and the sight of touch in the human brain. Soc Cogn Affect Neurosci 3:97–108
McGlone F, Olausson H, Vallbo A, Wessberg J (2007) Discriminitive touch and emotional touch. Can J Exp Psychol 61:173–183
McGlone FP, & Spence C (2010). Editorial: The cutaneous senses: Touch, temperature, pain/itch, and pleasure. Neurosci Biobehav Rev 34:145–147
McGlone F, Olausson H, Boyle JA, Jones-Gotman M, Dancer C, Guest S, Essick G (2012) Touching and feeling: differences in pleasant touch processing between glabrous and hairy skin in humans. Eur J Neurosci 35:1782–1788
Montagu A (1978) Touching: the human significance of the skin. Harper & Row, New York
Morrison I, Björnsdotter M, Olausson H (2011a) Vicarious responses to social touch in posterior insular cortex are tuned to pleasant caressing speeds. J Neurosci 31:9554–9562
Morrison I, Löken LS, & Olausson H (2009). The skin as a social organ. Exp Brain Res 204:305–314
Morrison I, Löken LS, Minde J, Wessberg J, Perini I, Nennesmo I, Olausson H (2011b) Reduced C-afferent fibre density affects perceived pleasantness and empathy for touch. Brain 134:1116–1126
Moseley GL, Gallace A, Spence C (2012) Bodily illusion in health and disease: physiological and clinical perspectives and the concept of a cortical body matrix. Neurosci Biobehav Rev 36:34–46
Olausson H, Cole J, Rylander K, McGlone F, Lamarre Y, Wallin BG, et al. (2008). Functional role of unmyelinated tactile afferents in human hairy skin: Sympathetic response and perceptual localization. Exp Brain Res 184:135–140
Park S, Hong KE, Park EJ, Ha KS, Yoo HJ (2013) The association between problematic internet use and depression, suicidal ideation and bipolar disorder symptoms in Korean adolescents. Aust N Z J Psychiatry 47:153–159
Rodgers C (2013) Why Kangaroo mother care should be standard for all newborns. J Midwifery Womens Health 58:249–252
Schaefer M, Heinze HJ, Rotte M (2012) Embodied empathy for tactile events: interindividual differences and vicarious somatosensory responses during touch observation. Neuroimage 60:952–957
Schaefer M, Rotte M, Heinze HJ, Denke C (2013) Mirror-like brain responses to observed touch and personality dimensions. Front Hum Neurosci 7:227. doi:10.3389/fnhum.2013.00227
Schneiderman I, Zagoory-Sharon O, Leckman JF, Feldman R (2012) Oxytocin during the initial stages of romantic attachment: relations to couples' interactive reciprocity. Psychoneuroendocrinology 37:1277–1285
Shermer M (2004). A bounty of science. Scientific American, 290(2), 33
Spence C (2011) Assessing the consequences of tool-use for the representation of peripersonal space in humans. In: McCormack T, Hoerl C, Butterfill S (eds) Tool use and causal cognition. Oxford University Press, Oxford, pp 220–247
Spence C, Deroy O (2013) Crossmodal mental imagery. In: Lacey S, Lawson R (eds) Multisensory imagery: theory and applications. Springer, New York, pp 157–183
Spies SLA, Margolin G (2014) Growing up wired: social networking sites and adolescent psychosocial development. Clin Child Fam Psychol Rev 17:1–18
Teneggi C, Canzoneri E, di Pellegrino G, Serino A (2013) Social modulation of peripersonal space boundaries. Curr Biol 23:406–411
Wagner J (2008) The making of second life. Harper Collins, London
Ward M (2007) A very real future for virtual worlds. BBC News, 14 December. http://news.bbc.co.uk/2/hi/technology/7144511.stm
Williams JR, Catania KC, & Carter CS (1992). Development of partner preferences in female prairie voles (Microtus ochragaster): The role of social and sexual experience. Horm Behav 26:339–349
Yilmaz U, & Aksu M (2000). The postejaculatory refractory period: a neurophysiological study in the human male. British Journal of Urology International, 85, 1093–1096
Zappella M (1967) Placing and grasping of the feet at various temperatures in early infancy. Pediatrics 39:93–96