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Affective touch: a communication channel for social exchange

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Bridging the gap between the neurophysiology of C-tactile mediated touch and the psychology of how social touch makes us feel, we present a definition of affective touch as mediated through CT afferents. We clarify how gentle stroking activating the CT system communicates a signal for social exchange. We describe what is already known about the nature of this signal and how it is perceived as a function of multisensory input and individual differences. Reviewing sender-specific and receiver-specific effects, we bring these streams together to outline a hybrid communication model of affective touch. We propose that affective touch should not be operationalized by simply involving CT afferent activation and a narrow range of stimulation modes, but instead should consider the entire communication chain: signal, receiver, sender and the dynamic exchange between interacting agents. Such a complete communication model presents new research directions to disentangle bottom-up and top-down mediated effects on perception.

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Existing work on affective touch relies on relatively abstract theoretical accounts of social exchange and social bonding. Additionally, studies have focused on the behavioural, physiological and neural responses to receiving affective touch with relatively little known about the benefits or motivation that drives us to reach out and touch someone else, or to seek touch from someone else. The skin has previously been described as a social organ through which tactile information is exchanged between individuals [1]. Therefore, as an analogue to a recently proposed dual-function communication model for another non-verbal exchange, namely eye gaze [2], here we resituate the study of affective touch within its natural interactive and reciprocal context. Importantly, we highlight that like other communication models, touch signals can be received but to do so they must be sent, and this is often done with some communicative intention. We suggest that for the special case of social, affective touch, a hybrid communication model may be of most use: on the one hand a simple transaction model [3] could prove useful to highlight the less-well established perceptual experience of the sender as well as the nature of the signal sent and, on the other hand, an interaction model [4] might capture the more dynamic and reciprocal nature of social exchanges through touch. We believe this communication-based account of affective touch is useful to identify future research gaps. Also in this issue, Schirmer, Croy and Schweinberger suggest an alternative conceptualisation for consideration. Here, we first describe the basis of a communication model, relating it to existing work in the field followed by the open questions and therefore potential future avenues this framework opens up.

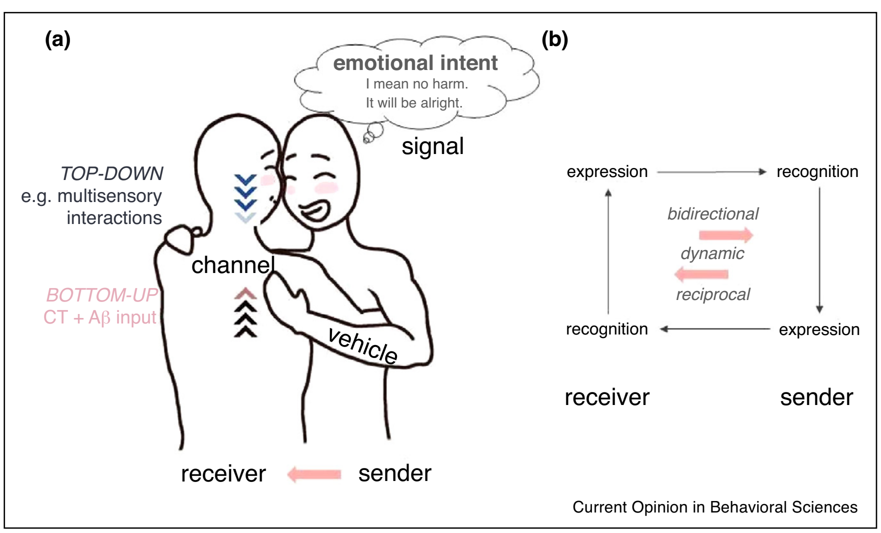
CT-mediated touch: a channel and signal for social exchange

According to general communication models, encoded messages are sent through a *channel*, a sensory route on which a signal travels, to the receiver for decoding. So too for non-verbal, social exchanges through affective touch for which we propose the key channel is the C-tactile (CT) system. The CT mediated touch system is fit for transmission, ensuring maximum efficiency of a sender to transmit a message to a receiver, through a channel with more or less interference [5], as evidenced by its prolific use across cultures for non-verbal exchanges. Several recent reviews (including Croy *et al.*, in this issue) highlight the significant progress made in identifying what we see as the channel for the invaluable transmission of affective content mediated by the CT afferent system. Types of touch that stimulate this channel range from single instances of touch (i.e. a comforting stroke on the shoulder), to ritualised, reciprocal exchanges like rubbing noses or a hug. Here we focus on types of affective touch that activate the CT nerve fibres and make specific reference to how these gestures may be targeted to particularly social zones like the back and shoulder where CT innervation, based on an animal genetic visualisation study by Liu *et al.*, is presumably highest ([6] — see also Ref. [7] for reference to the 'hedonic homunculus'). We do so by detailing the communication chain as captured by a simple transaction model where a single signal is sent from sender to receiver (Figure 1a), or an interaction model which covers more complex, reciprocal exchanges between interacting individuals (Figure 1b). For both cases, we highlight the importance of the *signal* which refers to the intended message that can be delivered through that channel. The *vehicle* is the touch gesture (i.e. a gentle caress, or a hug) which stimulates the CT system. By breaking it down in this way, one can separately investigate the communicative intent (e.g. harm or no harm; comfort; greeting), the gestures used to communicate this intent (e.g. multi-finger stroke versus whole hand hold, see [8•]), the signal (as it passes up the CT system), and indeed the other factors that modulate the signal and thereby the perceived / decoded experience at the level of the receiver.

A nice way to exemplify the usefulness of this reduced approach is that the signal or message may be the same (for example, comforting a loved one — 'things will be alright'), but may be communicated through multiple vehicles, such as using different forms of touch as befitting the social setting, and indeed activating different/ multiple channels, for example through eye gaze processed through the visual channel or a caress processed through the CT-system. However, a key question that must be answered if trying to establish a communication model of affective touch is: what is specifically communicated by the affective touch system? In the following section, we detail various research streams that have described what may be communicated by touch generally and the CT touch system specifically.

Previous work on this communicative function of touch describes the role it plays during the initiation of social interactions, showing that touch can promote a strong sense of togetherness and social support [9]. In shorter exchanges, such as inadvertent physical interaction on public transport or in a restaurant, touch has been shown to have a positive effect on compliance and result in spontaneous helping [10]. These examples represent the simpler and richer forms of exchanges that involve touch, again highlighting a need for a hybrid model of touch which captures the one-shot nature of an inadvertent hand on the shoulder or a more interactive reciprocal exchange. Focusing in on the intended message and taking an engineering approach, Yohanan and MacLean have operationalised and coded tactile exchanges into a touch dictionary that is used by their 'haptic creature' to decode and recognise expressive touch signals [11]. These touch signals were rated to describe emotions ranging from distressed and depressed to excited and

Figure 1



A hybrid communication model of affective touch.
(a) A typical exchange through touch will involve a (i) **sender,** the individual who initiates through touch, the (ii) **receiver** — the person who is touched (though these roles may be reversed through iterative exchanges),(iii) a **vehicle** of the communicated message — the soothing touch, (iv) the **intended affective signa**l, and the (v) **channel**, the slow conducting CT fiber system which likely is modulated through interactions with the fast Aβ afferents as well as multisensory processing of socially relevant stimuli. **(b)** Social touch should be seen as both bidirectional, reciprocal and dynamic in which expressive **feedback** from the receiver when a non-verbal signal is recognised and decoded is the next iteration in the communicative exchange.

aroused. Beyond their original touch dictionary, Hauser *et al.* define and measure in a 3D plane, parameters that define the nature of communicative touch-based interactions. Specifically, they take into consideration parameters that could be attributed to the 'sender', 'receiver' or both and include the intensity and velocity of the toucher's hand as well as the duration and area of contact made with the individual being touched [8•]. Others have gone so far as to specify the precise content of communicative touch, suggesting that touch can effectively convey intimate emotions [12,13]. But can we really attribute all of these communicative intents to CT-mediated touch? In our opinion, the issue of defining CT-mediated touch is hampered by various coexisting constructs for different types of touch. Therefore, we have developed some working definitions in Table 1 to facilitate communication. We do ascribe 'communication' properties to a single neuron and its stimulation by specific forms of touch, like a gentle caress or hug as evidenced by work by Hauser *et al.* using microneurography and recording responses to different gestures like these from single units. Specifically, we propose that social touch can be defined as an exchange between at least two individuals, and which depends on the activation of both touch systems as well as integration with other socially relevant sensory information. Across the various forms of touch, we therefore highlight the complementary or integrative action, as discussed below.

A key divide between the two main forms, namely CT-mediated affective touch and Aβ-mediated discriminative touch, (see Ref. [14]) is that the information that is communicated by the slow CT system, rather than descriptive or informational, is evaluative and motivational [20]. Whenever we are touched on CT innervated body sites, CT fibres send signals to the central nervous system preceded by information from the faster discriminative system, the advanced guard, reaching the cortex 1000's milliseconds earlier [14]. Recent work by Marshall and McGlone posits that CT afferents might not necessarily have an exclusive, unitary role in affective tactile coding, but rather shape ascending dorsal horn projection neuron outputs, which in turn affect the response to CT-optimal velocity touch [21••,22]. The authors suggest that the full expression of pleasant touch therefore depends on concomitant input through the faster discriminative system. Providing complimentary evidence of how the two systems of touch interact, Hagberg *et al.*, use magnetoencephalography to identify separable temporal posterior insula activations induced by both Aβ and CT afferents, which the authors suggest may underpin the modulating effect on the emotional processing of gentle touch on the hairy skin [23••].

This integrative view of touch can be complimented by the understanding of co-location seen in other sensory modalities. We have described how rich, social signals might be exchanged through the spatial co-location of diverse, functionally distinct sensory channels in the skin. As an analogue, let us consider the co-location of our senses of olfaction and trigeminal perception or indeed smell and taste. Both are clearly distinct sensory channels; however, this information often converges to provide a unified perception of 'smell' [24]. Additionally, cross-modal influences of smell and taste converge to produce the unified perception of flavour. Similarly, even from an early age, affective touch information is integrated with or modulated by other socially relevant cues from other modalities [25•,26,27]. In social exchanges with touch, the integration both within (two types of touch) and across modalities (e.g. affective touch and vision, see also Ref. [28]) may explain the confusion and difficulty in defining the different forms of touch and the information they convey. Further clarity is required to properly define what is meant by affective touch and what contribution the CT afferents make in terms of conveying affective content, that is, what signal is transmitted. These multisensory contributions to social touch, that is the sight, sound and smell of the person touching us, may explain why laboratory experiments like those using a robot are not ecologically valid. Conversely, ecologically valid experiments make it difficult to specify the specific influence of the touch.

It is now accepted that the CT system allows for a signal to be peripherally generated and centrally decoded as 'pleasant', communicating basic affective intent. Importantly, our recent work has shown that despite an averaged inverted-U shaped curve that highlights the optimal speed of stroking at the group level, the majority of individuals do not show this now classical parabolic function across stroking speeds [29]. Additionally, individual differences like autistic quotient have been shown to flatten this curve [30]. This inter-individual and intra-individual variability in how the touch signal is perceived may vary depending on several factors. In terms of the proposed model, these may include factors relating to *where* (body location [6,31,32], *what* (discriminative properties e.g. temperature [33]) and *how* (e.g. velocity of stroke [33,18]) affective touch receptors are stimulated and *with what intended meaning* [8•,34]. These controlled manipulations have allowed us to explore the bottom-up nature of the CT touch system. However, there is quite a gap between those laboratory studies and human behaviour, and different affective touch types. Only recently have gestures such as hugging, kissing or embracing been mapped out in terms of body areas involved or activation of CT fibres (see also [36] for discrepancies between ecological and lab-based settings, and [37•] for a recent article identifying a deep pressure response to hugging showing overlap with CT-like brain activity). Putting the signal to one side, we move now to describing the sender and receiver and the nature of the exchange between interacting agents.

Table 1

Working definitions for affective touch research

Type of touch	Definition	Example	Key reference
CT-mediated touch	Touch with properties suited to activate CT fibers	Slow, gentle stroking on hairy skin of the face, forearm or back.	McGlone *et al.* [14]
Affective touch	Touch with a (positive) affective valence; Such affective valence can be mediated without CT fiber involvement but is learned from CT input and CT input makes also non-interpersonal touch affective	Affectionately laying a hand on another person's arm (with or without stroking)	Gordon *et al.* (2013) (for neural correlates) [15];
Social/Interpersonal touch	Direct body to body touch between at least two individuals; depends on the activation of both touch systems as well as integration with other socially relevant sensory information	A hug, handshake or pat on the back.	Gallace and Spence (2016) [16]
CT fibres	C-tactile nerve fibres	Found in the hairy skin of the body.	Vallbo *et al.* (1993) [17]
CT response characteristics	Slow, low force, stroking stimulation delivered at skin surface temperature.	Inverted U-shaped response curve with greatest firing at CT-optimal velocity (3 m/s — 'not too fast and not too slow')	Löken *et al.* [18]
CT projection pathways	Posterior insula, striatum, OFC, STG	CT stimulation CTs carries a positive affective valence.	Morrison (2016) [19]

Senders, receivers and the processing of affective touch signals

One can describe affective touch in terms of whether changes in what is perceived is due to the nature of the sender or the receiver [38]. Manipulations at the receiver end of the exchange have focused on the neurobiological bases of perceptual differences across individuals. These have included studies into bottom-up centered mechanisms such as investigating an individual's genetic make-up (where a NGFB mutation influences C-tactile afferent density and subsequent perception of the hedonic aspect of dynamic touch [39]) and personality traits (e.g. lower affective touch awareness in patients with autistic traits [40]). By contrast, others have looked at the integration of additional sensory signals (e.g. visually induced analgesia [41]; body posture [42]) or the role of prior touch experience [37•,43,44], thereby exploring more top-down mediated effects. Additionally, the relation between the sender and receiver seems to determine how touch is processed and perceived [26]. People in close relationships, such as friends and partners, accept more parts of their body being touched [32], tend to use more intimate types of touch, like hugging as opposed to handshaking [45] and even stroke each other slower as opposed to people in more distant relationships [46]. More recently, Lo *et al.* have elegantly described 26 motion parameters used to stroke oneself, a social and non-social touch target, that is how one would stroke one's own arm, a foam arm, a dog, or a partner, so as to provide comfort [47]. They showed that social interaction partners are stroked with more movement variance than non-social ones. Employing virtual representations of people and non-human objects, Bailenson and Yee explored touch profiles, and specifically the force used, from the sender's perspective [48]. Interestingly, they show that less force was used when touching people than nonhuman objects, and that people touched the face with less force than the torso area. Additionally, a gender specific effect of the nature of the receiver with male digital representations touched with more force than female representations irrespective of the gender of the sender.

Beyond the relationship between sender and receiver, efforts have been made to manipulate who provides the touch input (nature of the sender) and its impact on perception of the receiver. Ellingsen *et al.* [27] detail what they describe as context driven changes in hedonic meaning reviewing several lines of evidence that show altered perception of touch as a function of the 'sender' even in cases where the modulating stimuli (e.g. visual [26,34] or olfactory cues [49]) are clearly unrelated to the source of the tactile input. There is however a contrasting line of research in which the true source of the touch stimulus is manipulated which more clearly delineates top-down and bottom-up mediated responses. For example, with relevance to an ever growing importance of social-care robots [50], human-robot interactions and mediated-touch [51], Triscoli *et al.* have compared how touch is perceived when delivered by a human performing a brush-stroke or a machine, finding that pleasantness ratings were very similar in both conditions [52]. Interestingly, these effects held even when participants were aware of the source (the sender) of the touch [52] and also when the human stroking is performed by hand and not by brush [53]. Employing static touch, which activates both CT [54] and non-CT touch fibres, Schirmer *et al.* similarly have shown that irrespective of whether touch was attributed to a friend or a machine, comparable responses both in terms of visual attention and emotion discrimination by the receiver are observed [55]. More recently, Pirazzoli *et al.* have investigated the social nature of the source of affective (CT-optimal) touch in 5-month-old infants and show no real condition-specific activation for body temperature-hand stimuli but suggest instead that they may need additional (multisensory) social cues to identify touch as affective [56•]. Of course, in our daily routines, we may in fact touch ourselves when applying face cream or washing our hair, in which case we are both the sender and receiver. Several studies have therefore explored the difference between self and other mediated touch with the recent work by Boehme *et al.* showing that, in neurotypical participants, there are distinctions at a neural level in terms of how self-related and other-related touch is processed in somatosensory, social cognitive, and interoceptive processing areas (e.g. see Ref. [57]). Of particular note, the lack of associated BOLD-related activity in somatosensory areas in the 'self' condition mirrors and may explain the distinct phenomenological experience of other-related touch. By identifying the individual components of the communication chain, one is more likely to disentangle and correctly attribute the action of the channel/CT nerve fibres (the 1st order neuron) which will respond irrespective of what stimulates (i.e. social or not) from the effects of additional components in the chain that can modulate the perceived experience. To make this point, an interesting juxtaposition can be made between the study by Ackerley *et al.* who reported that human touch (either self-touch from the participant or the touch delivered by the experimenter) to the face is perceived as less pleasant than the arm [58] while Essick *et al.*, by stroking the skin using a computer-interfaced servo motor showed the opposite effect (face > arm) as CT innervation predicts [59].

But what of the experience of the sender: why do we reach out to touch others? There is still a relative bias within the field towards the receptive experience of interpersonal exchanges through touch (for an exception from non-human research see Ref. [60]). One notable exception is a study by Ebisch *et al.* who explore subjective pleasantness and neural activation during an anticipatory phase when intending to touch either a real or fake hand with either one's own hand or with a massage brush [61]. The authors report a main effect of target such that the intention to touch a real hand is rated as more pleasant with correlated increased activation in the prefrontal cortex and greater deactivation in primary somatosensory cortex. In the next section we explore further novel research directions that are brought to bear by analysing the individual components of the communication model.

Future extrapolations of the communication model of affective touch

Based on the previous paragraphs, we make a case for a more formalised communication model of intended, affective touch that makes use of the CT system. This kind of model describes communication as an interdependent process where the sender and the receiver are simultaneously sending and receiving messages [2]. Whether greeting, comforting, or bidding someone farewell, the sender initiates an exchange by sending an affective signal through a vehicle, like a comforting caress, which activates CT afferent receptors, in these cases for example, in the densely CT innervated back [6]. The affective signal is received and recognised by the receiver who perhaps sends a reciprocal signal back, by leaning into the shoulder or hugging back. This expression is then recognised by the original sender. It is perhaps important to note that the feedback from the initial receiver need not be in the form of touch — instead a sigh or a change in eye gaze are other forms of sensory feedback that close the loop. This is evidenced by the fact that touch primes us towards processing of facial emotions even when the touch is not directed to ourselves [62]. This circle builds and reinforces a touch-based interaction. The conceptualisation of a dynamic touch-based interaction neatly parallels other models of dyadic nonverbal interaction [63]. Importantly an aspect of these types of models, which is as yet under investigated, is the reciprocal way in which individuals touch each other. Related models of social alignment highlight the role of dopaminergic reward systems to maintain dynamic, recursive social interactions that depend on feedback [2,64]. So too in social touch where the toucher may receive rewarding feedback in the form of a smile, a loving look or indeed in the form of a touch response. These recursive forms of touch are rarely studied and may be useful to further our understanding on the feedback component in this model.

The interaction depends on both interacting partners, their actions and the recognition of their intended expression. As such, we see that the interaction, although mediated by the intrinsically rewarding CT afferent system, will further depend on contextual factors and expectation. Therefore, there are further components of a communication model that more completely detail an exchange through touch. These may include *encoding*, where the sender transforms their intent into a meaningful signal. Compared to signal decoding, the encoding of affective intent is far less well-explored. A recent study by Hauser *et al.* explored what strategies are used by a sender to convey a set of communicative terms (e.g. loving, attention, happiness, sadness) as well as how these are perceived by the receiver [8•].

As detailed in our anecdotal scenario above (Figure 1), *feedback* could present a new research focus that may yield interesting perspectives on the function of affective touch communication as it captures the response to the sender's original message which in turn can be seen as the next iteration in the recursive dialogue through touch. Additionally, *context*, should and has been previously considered as the conditions surrounding communication with others [27]. Relevant to this is the idea that, like in many other sensory systems, attention has turned to investigating the role of multisensory interactions. Future work should continue to assess at what level(s) of the nervous system (and indeed the communication stream detailed in our model) does multisensory information related to touch interact or become integrated? With regards to *intent*, a further research opportunity is to explore the mismatch between the expected and received signal ('impression management'). The sender may for instance mean harm and yet touch the receiver in such a way as to hide this (for example by being overly friendly). Conversely, the sender may mean to comfort and yet evoke disgust. These mismatches in intent and perception are probably best also to study in relation to context and multisensory input. An additional important contribution of multisensory input may be that it underpins attentional capture by touch. Lastly, as in other communication systems, *noise* may need to be considered: that is any intended or unintended stimulus that affects the fidelity of the message and disrupts the communication process. These can be either external — stimuli that draw our attention away from the intended message or internal — our own thoughts or feelings that prevent us from processing a sender's message, for example based on prior experience or individual differences in preference for touch. These aspects of social and affective touch represent significant new avenues for future research. For example, research is only now beginning to detail the reciprocal benefits of affective touch to the sender, how the sender-receiver interaction shapes the touch signal and how touch interactions evolve over time. To this end, one might consider exploring the dynamic time-course of responses to CT-optimal stimuli, especially in longer and reciprocal touch interactions. This approach has already been implemented by Lo *et al.* who have described the pleasurable spatio-temporal variability of social stroking [47]. Moreover, Haberg *et al.*, show time-profile differences in slow and fast touch [18••], (see Refs. [65,66] for further examples of studies looking at physiological responses).

Conclusion

To make our case as to the usefulness of a hybrid communication model of affective touch, we have first detailed the role played by CT afferents as a central channel through which affective content is communicated. We have then reviewed the existing research divided up as a function of the individual components of the communication chain. We posit that this approach will work to counter existing disciplinary biases towards the receiver in the exchange so that on the one hand greater emphasis can be placed on the experience of the sender and the nature of the signal and on the other that this will drive a more interactive and therefore dynamic view of reciprocal exchange through touch. We believe that these more formalised models are necessary to not only identify new avenues of research but also to better disentangle top-down and bottom-up mediated effects on perception.

Conflict of interest statement

Nothing declared.

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Given his role as Guest Editor, Francis McGlone had no involvement in the peer-review of this article and has no access to information regarding its peer-review. Full responsibility for the editorial process for this article was delegated to Annett Schirmer.

Declaration of Competing Interest

The authors report no declarations of interest.

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