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Review article

Social touch experience in different contexts: A review

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ABSTRACT

Social touch is increasingly utilized in a variety of psychological interventions, ranging from parent-child interventions to psychotherapeutic treatments. Less attention has been paid, however, to findings that exposure to social touch may not necessarily evoke positive or pleasant responses. Social touch can convey different emotions from love and gratitude to harassment and envy, and persons' preferences to touch and be touched do not necessarily match with each other. This review of altogether 99 original studies focuses on how contextual factors modify target person's behavioral and brain responses to social touch. The review shows that experience of social touch is strongly modified by a variety of toucher-related and situational factors: for example, toucher's facial expressions, physical attractiveness, relationship status, group membership, and touched person's psychological distress. At the neural level, contextual factors modify processing of social touch from early perceptual processing to reflective cognitive evaluation. Based on the review, we present implications for using social touch in behavioral and neuroscientific research designs.

1. Introduction

As the most fundamental form of contact, social touch is commonly used to relieve stress, build a sense of togetherness, and convey feelings of love and sympathy. Accordingly, social touch has been increasingly utilized in a variety of behavioral interventions: for example, in psychotherapies (e.g., for traumatized or neuropsychiatric patients) (Phelan, 2009), in parent-child interventions (Field, 2010), and in other health-care settings to improve quality of patient-physician interactions (Anderson and Taylor, 2011). There is also evidence that social touch has potential to increase friendly and prosocial behavior in the target person (known as "the Midas touch") (Crusco and Wetzel, 1984). For example, exposure to social touch is found to increase bus driver's willingness to get customers into the bus without having enough money for the ticket (Guéguen and Fischer-Lokou, 2003), target person's willingness to look after a large dog (Guéguen and Fischer-Lokou, 2002), willingness to give a cigarette to a stranger by request (Joule and Guéguen, 2007), to participate in a survey (Hornik and Ellis, 1988), and to give money to charity (Kurzban, 2001), although also null findings exist (Guéguen et al., 2011). Along with possible prosociality-enhancing effects, social touch has arisen interest also in the research field of prejudice since social touch is postulated to effectively reduce prejudices between different social groups (Seger et al., 2014).

However, in order to expect positive effects of social touch (e.g., lower stress levels, increased opioid release, sense of togetherness, reduced prejudices), immediate touch exposure should be experienced as pleasant (Martin, 2012; Shamloo et al., 2018). This is an important notion as exposure to social touch may not necessarily be a positive or pleasant subjective experience. Touch can convey a wide variety of different emotions, including positive and negative emotions, self- and other-focused emotions, and emotions with low or high arousal (J. W. Lee and Guerrero, 2001; Thompson and Hampton, 2011). For example, touch can convey signals of anger, disgust, fear, gratitude, harassment, formality, happiness, love, sadness, sympathy, embarrassment, envy, pride, or surprise (J. W. Lee and Guerrero, 2001; Thompson and Hampton, 2011). In addition, real-life touch exposures and wishes for touch are not necessarily in synchrony with each other: some types of social touch are experienced more often than wished (e.g.,

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hand-shaking), whereas some types of touch are experienced less often than wished (e.g., hugging or stroking) (Beßler et al., 2020). To date, most studies have focused on social touches that are experienced as pleasant, positive, or congruent with other contextual cues (e.g., facial expressions), whereas less attention has been paid to unpleasant or incongruent experiences of social touch. Along with this, it has remained unclear which kinds of contextual factors modify target person's behavioral responses to social touch.

Interestingly, previous research literature suggests that contextual factors modify responses to social touch also at the neural level (Ellingsen et al., 2015; Kirsch et al., 2018). Although there are some differences in the neural processing between different sorts of touches (e.g., CT-optimal touch, or hand holding), there are some common phases of processing social touch. First, before touch, there are anticipatory responses in the prefrontal and parietal cortex that adjust later phases of touch processing in a top-down manner (Carlsson et al., 2000). After social touch exposure, the tactile signal is generally first transmitted through a spinothalamic tract to the thalamus. From there, the signal is mediated to the primary and secondary somatosensory cortices, the insula, and other cortical regions, such as the prefrontal cortex, the orbitofrontal cortex, the anterior cingulate cortex, and the superior temporal sulcus (Ellingsen et al., 2015; Gliga et al., 2019; Scheele et al., 2014). Moreover, the ventral striatum and amygdala are involved in the processing of social touch (Gliga et al., 2019). Along with the multi-directional connections between the brain regions, subjective experience of social touch is influenced by both bottom-up and top-down factors such as toucher-related or contextual information (Ellingsen et al., 2015; Kirsch et al., 2018).

In previous studies, social touch has been defined in two ways: (1) in terms of sensory qualities of touch (i.e., defined as a "CT-optimal touch" that occurs with velocity of 3 cm/s, targets CT-fibers on the skin, and is experienced as a gentle caress), or (2) in terms of interpersonal and intentional aspects of touch (i.e., whether there are affective signals conveyed by touch) (Gliga et al., 2019). In the former case, touching certain body regions in a specific way can be considered as social touch. In the latter case, different types of touches (e.g., tapping on shoulder, embracing, holding hands, and caressing) qualify as social touch as they convey information about toucher's feelings and intentions toward the received. Depending on the line of research, previous studies have used different terms to refer to social touch, including e.g. social touch, affective touch, interpersonal touch, or CT-optimal touch. Here, we use the term social touch to refer to all different types of touches with affective influence or social meaning.

This review investigated the modifying roles of psychosocial situational factors and toucher's characteristics for touched person's immediate responses (including affective, behavioral, perceptual, and neural responses to touch). This kind of review provides useful implications for touch-based research designs and increases understanding of previous partly inconclusive results of touch-based studies. The focus area of this review is shown in Fig. 1.

2. Methods

2.1. Literature search

A systematic literature search was conducted (PubMed). We used the following search terms: ("emotional touch" OR "affective touch" OR "social touch" OR "interpersonal touch" OR "friendly touch" OR "gentle touch" OR "touch aversion" OR "touch avoidance" OR "CT-optimal touch"). The search was directed to titles and abstracts with no restrictions regarding publication year (published by February 2021). After identifying eligible original articles, the reference lists of the eligible articles were screened. The literature search process is illustrated in Fig. 2. The results of the literature search are presented in Table 1. We found altogether 99 eligible original studies (six studies of them investigated more than one contextual factor). A list of the included articles can be found in **Supplementary Table 1**.

2.2. Inclusion criteria

We had the following inclusion criteria for peer-reviewed original human studies examining: 1) immediate responses to social touch ("social touch" defined as a skin-to-skin contact between humans, a CT-optimal touch, or a touch that appeared to be coming from a virtual character); 2) psychosocial contextual factors influencing responses to touch; 3) the target person's responses to social touch (in case of bidirectional types of touches such as hugging or hand-holding, both persons were interpreted as target persons); 4) adult populations; 5) non-clinical populations; 6) non-erotic forms of social touch; and 7) quantitative studies ($n > 10$).

2.3. Exclusion criteria

We excluded studies examining: 1) long-term developmental influences of touch (that have been reviewed previously (Cascio et al., 2019; Weller and Feldman, 2003); 2) the modifying roles of sensory

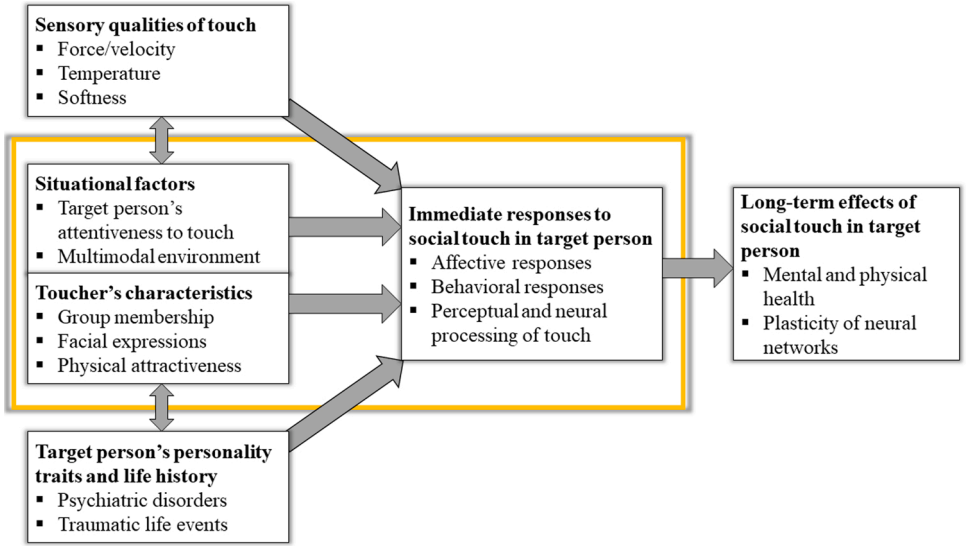

Fig. 1. Focus of the literature review (marked with a yellow square).

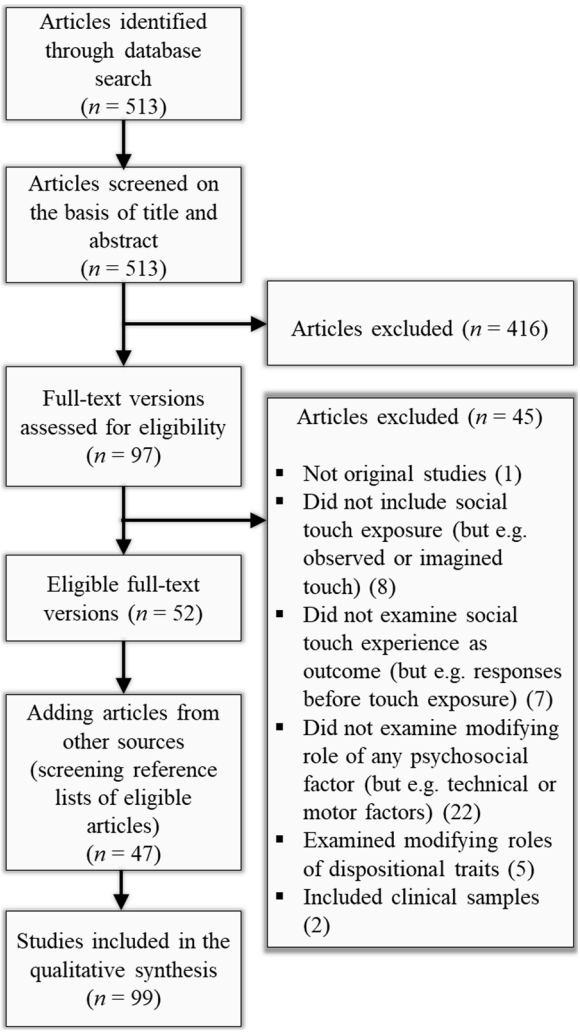

Fig. 2. The article selection process for the current review.

Table 1
The results of the literature search: number of original studies that were reviewed.

Contextual factor under investigation	Number of original studies that were reviewed
Toucher's group membership and prejudices	11 studies
Receiving touch from a familiar person	
Touching patterns in private and public contexts	13 studies
Situations without experimentally induced psychosocial stress	16 studies
Situations with exposure to psychosocial stress	13 studies
Receiving touch from a stranger vs. receiving no touch	15 studies
Responses to CT-optimal touch	13 studies
Facial expressions of toucher	4 studies
Physical attractiveness of toucher	5 studies
Multimodal qualities of the environment	6 studies
Target person's attentiveness to social touch	7 studies

qualities of touch, dispositional personality traits, or previous life events for touch experience; 3) imagined touches or object-induced non-CT-optimal touches; 4) toucher's responses to social touch experience; 5) infant or child populations; 6) clinical population studies since neuropsychiatric disorders can bias touch perceptions; 7) erotic forms of touch; 8) qualitative or theoretical studies; and 9) animal studies. In addition, previous reviews (Gallace and Spence, 2010; Russo et al., 2020; Taneja et al., 2021) have comprehensively covered the roles of sociodemographic factors (age, sex, socioeconomic status) and cultural factors for the experience of social touch. Consequently, those factors were excluded from this review.

3. Review of the findings

3.1. Toucher's group membership and prejudices

3.1.1. Behavioral and physiological responses

The reviewed literature suggests that toucher's in-group vs. out-group status or prejudices toward different groups modulate the experience of social touch. First, in the 1970s, it was found that Black customers were more likely to touch other Black customers than White customers in cafeteria lines (when considering any type of touch) (F. N. Willis et al., 1978). Later on, it has been found that touch of a Black nurse (vs. touch of a White nurse) to measure heart rate predicts increased heart rate in European American recipients (Vrana and Rollock, 1998), indicating higher touch-induced physiological arousal during the touch by an out-group member. More recently, there have been studies examining also types of groups than than ethnic groups (e.g., people with a different sexual orientation, disease, or criminal background). Specifically, hand-shaking of a person stigmatized with a disease (e.g. leprosy), obesity, atypical physical appearance (e.g. an amputated leg), or criminal history is reported as more discomforting than hand-shaking of a person without such conditions (Park et al., 2013). Additionally, if a toucher is assumed to be homosexual, touch on arm during question has been shown to arouse an aversive emotional response and decrease compliance with toucher's request (i.e., to buy a product) in touch receivers with strong homophobia (Dolinski, 2010). Moreover, a hug between two men can be experienced as abnormal and unexpected among heterosexual men who interpret the hug as having sexual connotations (Floyd, 2000). Taken together, receiving a touch from a stigmatized person or minority-group member can be perceived as aversive and discomforting particularly by people with prejudices towards the respective out-groups.

Importantly, touch of an out-group member may be experienced differently at different stages of acquaintanceship. For example, physical contact (hand-shaking and exercises including touch) with an out-group member (Muslim) is shown to increase positive attitudes toward the whole out-group in White British adults only if the physical contact is not conducted during the first meeting but at later stage (Choma et al., 2018). The researchers suggested that this may reflect a need for "psychological preparation" (Choma et al., 2018). Thus, even one meeting before touch may possibly be enough to produce feelings of "psychological preparation". This is in accordance with the contact theory (Allport and Pettigrew, 1954) and related findings that frequent physical contacts with out-group members (e.g., foreigners) (this study examined any type of physical contact) predict more positive attitudes toward and more frequent future contacts with them but only if the (physical) contact is experienced as positive or pleasant (Shamloo et al., 2018). Hence, a touch with out-group members may not reduce prejudice effectively if it is occasional and/or experienced as unpleasant.

This topic has been investigated also in the context of sport-related intergroup interaction (i.e. cooperation vs. competition). In two experiments, subjects completed either a cooperative or competitive task in a group and simultaneously received touches on their shoulder from a group member (Camps et al., 2013). It was found that afterwards subjects, who were touched, gave higher credits to the group members in cooperative situations but lower credits to the group members in competitive situations (when compared to subjects who were not touched) (Camps et al., 2013). Related to this finding, an observational study reported that frequent touches (any types of touches) between basketball players of the same team predicted better performance (Erceau and Guéguen, 2007).

Overall, one explanation for the findings may be differences in the neural responses to in-group- and out-group members. Specifically, when interacting with in-group members (vs. out-group members), the dorsomedial prefrontal cortex exhibits stronger functional connectivity with the orbitofrontal cortex and ventral striatum (Rilling et al., 2008). As the striatum and orbitofrontal cortex are found to be involved in reward processing and hedonic experiences (Delgado, 2007; Kringelbach, 2005), this may imply that individuals experience more rewarding to be in interaction with in-group than out-group members. Closely related to this, it has been found that observing a touch on an out-group member's face (vs. in-group member's face) results in weaker sensory tactile perception (i.e., higher detection threshold) on participants' own face (Serino et al., 2009). This may imply that the mirror neuron system may respond differently when observing in-group vs. out-group member's touch.

3.2. Receiving a social touch from a familiar person vs. From a stranger or no touch

3.2.1. Touching patterns in private and public contexts

In the previous section, we noted that in intergroup context, touch of an out-group member may be experienced as unpleasant particularly in individuals with prejudices toward the concerning out-groups, and that touch may be more pleasant if an out-group member has become more familiar to target person (e.g., they have met several times). Interestingly, degree of familiarity may affect the experience of touch also in interpersonal context, where touch coming from a familiar person is experienced as more pleasant than touch coming from a stranger. Next, we review studies related to familiarity of toucher.

Overall, it is necessary to consider that touch behavior has been noted to include different patterns in public vs. non-public settings (Gladney and Barker, 1979; Henley, 1973; Major et al., 1990), with majority of touches occurring in private settings (especially in more intimate body areas) (F. N. Willis and Rinck, 1983). In accordance with these findings, there is evidence for higher frequency and need for touch (including any type of touch) between partners than between strangers (Beßler et al., 2020). Further, family members are found to express a wider array of emotions via touch than strangers: strangers commonly convey universal or prosocial emotions via touch whereas family members express also social control and negative affective states such as pride, envy, or psychological control or dominance, punishment, farewell, hurting, or scaring (Pisano et al., 1986; Suvilehto et al., 2015; Thompson and Hampton, 2011).

In addition, there are also differences in the body regions that are allowed to be touched by strangers vs. close acquaintances or romantic partners. Specifically, approximately 20 % and 70 % of the body regions are allowed to be touched by strangers and romantic partners, respectively (Suvilehto et al., 2015, 2019). The extent of touch-allowed body regions is positively related to the emotional bond with the toucher (Suvilehto et al., 2015, 2019). Strangers are allowed to touch the hands whereas closer acquaintances are allowed to touch also the head and upper torso (Suvilehto et al., 2015, 2019).

Likewise, observational and questionnaire-based studies have found that touch frequencies change from dating stage to post-marriage stages: touch frequency (including any types of touches) increases from the first stage of dating to more serious stages of dating but levels off or decreases after getting married (Emmers and Dindia, 1995; Guerrero and Andersen, 1991; F. N. J. Willis and Briggs, 1992). There are also substantial differences in the overall touch exposure between alone-living and married individuals (Trotter et al., 2018).

Overall, it appears that a stranger's, friend's, or partner's social touch may have partly different influences when a target person is under psychosocial stress *vs.* in circumstances without stress-prone situational factors. Thus, we next review those studies separately.

3.2.2. Situations without experimentally induced psychosocial stress

3.2.2.1. Physiological responses. Research evidence indicates that exposure to social touch is related to different physiological responses depending on the relationship status between the toucher and target person. Specifically, subjects who are stroked on their forearm by their partner exhibit reduced heart rate (when compared to no stroking) (Triscoli et al., 2017a,b). Similarly, an experiment implied that couples who are holding their hands have lower systolic blood pressure after the contact, although the experiment did not include any control condition without touch (Grewen et al., 2005). Also, touch (on the forearm) between romantic partners is related to increased heart rate variability which is a sign of lower physiological stress levels when compared to a condition without touch (Chatel-Goldman et al., 2014). Likewise, a questionnaire-based study reported that frequent exposures to partner's physical touch (without specifying type of touch) is related to lower systolic and diastolic blood pressure (J. E. Lee and Cichy, 2020).

Interestingly, the favorable effects of social touch on physiological responses appear to be particularly evident if the quality of the romantic relationship is balanced in the long run: if a couple experiences high mutual support (Grewen et al., 2005), is satisfied with their relationship (Triscoli et al., 2017a), or reports high quality of their relationship (J. E. Lee and Cichy, 2020). Instead, the intensity and valence of *momentary* emotions during a partner's touch seem not to modify the physiological effects of touch (Chatel-Goldman et al., 2014).

3.2.2.2. Affective responses. There is accumulating evidence indicating that touch by a familiar person is often subjectively experienced as positive and pleasant. Specifically, subjects who are stroked or caressed on their forearm or legs by their partner (or participants *suppose* that toucher is their partner) experience touch exposure as more pleasant when compared to self-touch or an object-induced touch (Kreuder et al., 2017; Nummenmaa et al., 2016; Triscoli et al., 2017a). Similarly, subjects who are touched to their hand by their partner during a cognitive task have higher positive affect and lower negative affect (compared to no touch) (Saunders et al., 2018). Further, subjects who were touched friendly on the shoulder during a group task experienced stronger feelings of community and higher gratitude when compared to those who were not touched (Simão and Seibt, 2015). In addition, a diary-based study found that frequent exposure to partner's touch (without specifying types of touch) is associated with stronger experience of psychological intimacy and higher positive affect (Debrot et al., 2013). Also, an observational study reported that frequent responsive touches (any types of touch) between dating couples predicted higher experienced social support (Robinson et al., 2015). Taken together, a touch coming from a partner seems to evoke on average positive affective responses.

3.2.2.3. Brain responses. Besides subjective experiences, a number of studies have examined neural responses: whether neural responses are different to touches by a partner or a stranger. There is evidence that hand-holding with a partner (compared to touch by a stranger or being alone) augments beta and theta power, possibly indicating lower emotional arousal (Kraus et al., 2020). During cognitive tasks, it has been found that holding hands with partner increases error-related neural monitoring (i.e., error-related negativity peaking 100 ms after making an error) and predicts improved inhibitory control in the task (when compared to no touch) (Saunders et al., 2018).

Interestingly, there may be different relationship-related modulations in the touch-induced neural responses at different phases of touch exposure. That is, the primary somatosensory cortex exhibits weaker activity during *anticipation* of a romantic caress but higher activity during *exposure* to a romantic caress when compared to a neutral object-induced touch (Ebisch et al., 2014).

Finally, the opioidergic system may play a role in the experience of social touch. That is, affective touch (CT-optimal touch) on the lower leg

is experienced as less pleasant after administration of opioid antagonist naloxone (Case et al., 2016) and, further, exposure to partner's non-sexual caress all over the body (*vs.* no touch) induces increased μ-opioid receptor availability in a variety of affect-related brain regions (e.g., in the thalamus, insula, striatum, and cingulate cortex) in a positron emission tomography (PET) study (Nummenmaa et al., 2016). Hence, even single social touch from a familiar person may produce obtainable changes in the opioidergic system.

3.2.2.4. Touch-specific effects. Importantly, all the experimental findings listed in this subsection compared target person's responses to partner's or friend's touch *vs.* being alone, self-stroking, or being touched by a stranger. Hence, effects of a partner's or friend's touch have not been compared to presence or non-tactile communication with a partner or friend. Thus, those studies have not provided evidence for any *touch-specific* effects.

There are, however, a few studies investigating touch-specific responses. First, it has been found that holding hands with a romantic partner induces greater interpersonal neural synchronization than vocal communication between partners, indicating that touch may play role in affiliative bonding (Long et al., 2021). Second, there is evidence that touch on the thigh, shin, or calf of both legs that was though to come from partner (or a toucher that participants suppose to be their partner, compared to merely partner's physical proximity or touch that was thought to come from a stranger) is associated with different activity patterns in the amygdala, somatosensory cortex, orbitofrontal cortex, and posterior cingulate cortex (Kreuder et al., 2017; Suvilehto et al., 2020). This indicates that there are also effects that are specific to partner's touch (and are not evoked by e.g. partner's presence). Furthermore, the findings imply that the processing of toucher's relationship status is integrated to the touch processing from early stages to more conscious and higher-level stages. In accordance with this, it has been emphasized that the affective and cognitive contextual factors of touch exposure may be processed in the primary somatosensory cortex and insula (Gazzola et al., 2012; Suvilehto et al., 2020).

3.2.3. Situations with exposure to psychosocial stress

A number of studies have been conducted under psychosocial stress situations where exposure to partner's or friend's touch seems to act as a stress-buffering factor and have also other favorable influences. Some original studies have investigated this issue during sensory pain (i.e., a bottom-up approach examining modifying roles of sensory stimuli on touch experience) and other studies during psychological distress (i.e., a top-down approach investigating modifying roles of cognitively processed contextual factors such as social exclusion).

3.2.3.1. Affective responses. It has been reported that subjects who are exposed to a picture of their deceased close acquaintance experience the situation more comfortable if simultaneously holding their hands with partner (*vs.* being alone without any skin-to-skin contact) (Coan et al., 2006; Kraus et al., 2019). Also, an interview-based follow-up study indicated that frequent exposure to hug with a partner is longitudinally associated with a smaller decrease of positive affect during conflicts and lower increase in negative affect after the conflict (Murphy et al., 2018). Interestingly, receiving a social touch may alleviate also one's experience of physical pain. That is, subjects who are exposed to heat stimuli and are touched on their hands by their partner are found to experience lower levels of pain (when compared to being touched by a stranger, only watched, or without any social interaction) (Goldstein et al., 2016). Similarly, during painful thermal stimulation, hand-holding with partner reduces experienced pain (when compared to holding a rubber ball) (Korisky et al., 2020). Finally, subjects who are threatened by an electric shock are reported to experience the situation less unpleasant if simultaneously holding their hands with partner (vs. holding hand of a stranger or being without any skin-to-skin contact) (Coan et al., 2006; Kraus et al., 2019). All these findings tentatively suggest that partner's touch may reduce sensory or psychological pain.

3.2.3.2. Physiological responses. Besides behavioral evidence, several studies have focused on physiological responses to partner's touch under psychological stress (i.e., related to top-down mechanisms of social touch). First, exposure to hand-holding and hugging with the partner is found to predict lower diastolic and systolic blood pressure and lower heart rate under psychosocial stress (to give a tape-recorded speech describing a distressing social situation), when compared to respective physiological responses during quiet rest before performance (Grewen et al., 2003). Interestingly, similar effects have not been found when exposed to friend's touch. That is, exposure to friend's touch on the wrist may not predict more favorable physiological responses (in heart rate or blood pressure) to psychosocial stress (when compared to being alone or exposure to touch of a stranger) (Edens et al., 1992). Hence, during induced psychological distress, a touch of a partner may possibly reduce physiological stress responses while evidence regarding touch of a friend is very limited.

3.2.3.3. Brain responses. Also neural responses to touch exposure seem to be modulated by the relationship status between the toucher and target person. First, some studies have investigated the influences of exposure to social touch during sensory pain. Specifically, subjects who are threatened by an electric shock have attenuated responses in the threat-related brain networks (e.g., in the anterior cingulate gyrus, the right dorsolateral prefrontal cortex, and the caudate) if they are holding their partner's hand (when compared to holding a stranger's hand or no hand) (Coan et al., 2006). In addition, during painful thermal stimulation, subjects who are holding hands with their partner exhibit stronger connections between the inferior parietal cortex and dorsomedial prefrontal cortex when compared to control condition (holding a rubber ball), indicating that social touch may reduce pain via the interaction between the executional and emotion regulation networks (Korisky et al., 2020). Moreover, during thermal pain stimulation, holding hands with partner also relates to altered activity patterns in various brain regions related to pain and affect regulation (i.e., in the nucleus accumbens, ventral striatum, amygdala, medial prefrontal cortex, inferior parietal sulcus) in subjects with reduced experienced pain (Reddan et al., 2020). Finally, subjects exposed to pain are found to exhibit reduced pain-related potentials of N1 and N2–P2 if they simultaneously receive an affective touch on the forearm from their partner (when compared to a non-affective touch) (von Mohr et al., 2018a,b).

One study investigated this issue from the top-down perspective (i.e., psychological distress). Subjects who are exposed to a picture of their deceased significant other are noted to have reduced activity in the anterior cingulate cortex (potentially referring to a lower need for emotion regulation) and a lower connectivity between the anterior cingulate cortex and insula (potentially referring to a lower level of experienced psychological pain) if they are simultaneously holding their partner's hand (when compared to holding a stranger's hand or being alone) (Kraus et al., 2019). Hence, this study suggests that social touch from a familiar person may reduce activity in brain regions related to pain processing and emotion regulation but more evidence is needed.

3.2.3.4. Touch-specific effects. Importantly, similarly to the previous subsection, it should be taken into consideration that all these experimental studies have compared touch of a partner or friend to being alone or receiving touch from a stranger. Instead, those studies have not examined whether partner's touch has touch-specific effects, i.e., compared responses to partner's or friend's touch to having non-tactile communication with a partner or friend.

There are, however, some studies investigating touch-specific effects. First, under virtually-induced feelings of social exclusion, subjects have lower levels of negative emotions and reduced activity in the anterior

insula if they receive a gentle touch on their hand from their friend (when compared to receiving informative support from their friend) (Morese et al., 2019). Additionally, there is evidence that subjects who are exposed to their partner's touch on the neck and shoulder exhibit lower cortisol and heart rate levels in response to psychosocial stress (a public speaking task and an arithmetic task in front of others), when compared to other types of interaction with the partner (Ditzen et al., 2007). Hence, it seems that not all positive responses to partner's touch can be explained by merely presence or non-tactile support of a partner, but there seems to be also touch-specific pain-reducing effects.

Finally, findings have been inconclusive regarding physiological *coupling* (i.e., inter-individual synchronization of physiological activity). Specifically, it has been reported that subjects who are exposed to pain and are simultaneously holding hands with their partner experience stronger physiological coupling in respiration and heart rate (*vs*. those who only see their partner present without touch) (Goldstein et al., 2017) and also increased brain-to-brain coupling between partners (Goldstein et al., 2018). One study, in turn, found that hand-holding with partner or receiving stroking from partner were not related to physiological coupling between the partners (in terms of skin-conductance responses) during pain, when compared to a condition without touch (Reddan et al., 2020). Hence, touch-related effects may be more consistent within target persons (when considering individual-level responses) than between touchers and target persons.

3.3. Receiving touch from a stranger vs. Receiving no touch during psychosocial stress

In the previous sections, it was noted that, during sensory or psychological pain, receiving a touch from one's friend or partner may more effectively alleviate pain when compared to a touch coming from a stranger. Nevertheless, evidence is inconclusive whether, during pain, being touched by a stranger alleviates pain more effectively than not being touched at all.

First, some studies have investigated this issue from the perspective of sensory pain (i.e., bottom-up contextual effects). Specifically, there is evidence that subjects, whose hands are immersed in ice water, experience ice water as less painful if being simultaneously touched on their wrist by a stranger (than not being touched and practicing alpha biofeedback) (Drescher et al., 1985). Further, one study reported that subjects who are threatened by an electric shock have attenuated responses in some threat-related brain networks (e.g., in the vACC, posterior cingulate, left supramarginal gyrus, and right postcentral gyrus) if they are holding a stranger's hand when compared to being alone (Coan et al., 2006). However, attenuated responses were not obtained in all hypothesized threat-related brain networks. Moreover, one study had null results: subjects who were exposed to heat stimuli or electric shock and were touched on their hands by a stranger did not report lower levels of pain or unpleasantness when compared to being alone (Goldstein et al., 2016). Taken together, it remains unclear whether a stranger's touch may alleviate *sensory* pain more effectively than being alone.

Second, other studies have investigated this topic from the perspective of *psychological* pain (i.e., top-down contextual effects). A widely-known experiment in the 1970s found that university students' task performance is reduced if they are touched on their shoulder by the experimenter without explanation during performance (when compared to only sitting in the same room without touching) (Sussman and Rosenfeld, 1978). Another study in the 1990s showed that exposure to a stranger's touch on the wrist predicted even higher heart rate and blood pressure in response to psychosocial stress (an arithmetic task and a mirror-tracing task) when compared to being alone (Edens et al., 1992). This is in accordance with another study in the 1990s indicating that holding hands with a stranger predicts increased heart rate when compared to no touch (Williams and Kleinke, 1993). Hence, these studies suggest that touch of a stranger may not necessarily have favorable influences.

More recent experimental studies in laboratory settings and more controlled research designs, in turn, have observed more positive influences of stranger's touch during stress exposure. For example, subjects, who are socially excluded in the Cyberball task, experience weaker feelings of social exclusion if they are affectively touched on their forearm (vs. neutrally touched) (von Mohr et al., 2017). Moreover, subjects who are playing a financial risk-taking game are more likely to conduct risky gambling if they are given a comforting pat on their shoulder by a stranger (vs. not given a touch or given a hand-shake) (Levav and Argo, 2010), implying that touch may reduce feelings of distress in a risky situation. Finally, subjects who have low self-esteem and are reminded of death, report lower death anxiety and stronger social connectedness if they are touched on their shoulder by a stranger (when compared to no touch) (Koole et al., 2014). Nevertheless, it is necessary to note that participants were not exposed to any death-related material and, hence, the results cannot be generalized to situations where mortality is made salient and participants are exposed to material arousing death anxiety. In another study, however, subjects were exposed to a picture of their deceased close other (i.e., death anxiety) and were noted to have reduced activity in the right caudate if they are simultaneously holding a stranger's hand (when compared to being alone) (Kraus et al., 2019).

Taken together, the findings on responses to stranger's touch seem to be quite different in the 1970–1990 s vs. in the 2000s. This may be related to cultural changes in touch frequency and touch norms because cultural factors, in general, are known to influence touch experience (Sorokowska et al., 2021). The differences may also be related to research methods: in the 2000s, the experimental designs have generally became controlled to a greater degree and methods to convey touch and assess touch experiences have been validated more accurately. Overall, it appears that evidence related to stranger's touch is much more inconsistent than evidence related to partner's touch.

3.3.1. Responses before vs. during touch

One study indicated that exposure to a socially distressing situation may have stronger positive influence on self-reported *wanting* of social touch (a soft caress on the forearm) from a stranger and *anticipatory* pleasantness of social touch than on experienced pleasantness of touch *during* touch exposure (Massaccesi et al., 2020). On the contrary, exposure to a pleasant situation may not have any influence on wanting or pleasantness of social touch from a stranger (Massaccesi et al., 2020). However, as there is only one study on this topic, no firm conclusions can be made.

3.3.2. Situational appropriateness of touch

Two studies have examined the role of situational appropriateness of touch experience when touch comes from a stranger. Specifically, one study found that exposure to a professional touch (with a clear aim to measure heart rate) reduces subjects' heart rate, blood pressure, and activity of corrugator and zygomaticus facial muscles (i.e., indicators of physiological arousal), when compared to touch without any justification or not being exposed to touch (Nilsen and Vrana, 1998; Vrana and Rollock, 1998). Second, in an experiment of the 1980s, subjects were asked to comply with a minor request, then touched or not on the upper arm, given a positive or negative description of themselves (e.g. "you are not very helpful"), and then asked to comply with an additional request (Goldman et al., 1985). The combination of touch and a negative description predicted highest compliance with toucher's further request (when compared to touch combined with a positive description) (Goldman et al., 1985). This was interpreted to indicate that a positive description may not be situationally appropriate for a minor request (Goldman et al., 1985).

Hence, the studies tentatively suggest that a stranger's touch may be more positively experienced if it is situationally appropriate. Nevertheless, it is necessary to consider that the studies did not confirm

whether participants experienced touch as "situationally appropriate". Additionally, the findings were obtained before the 2000s and more recent studies are needed. Therefore, the findings must be considered with caution.

3.4. Naturality of context: human touch and CT-optimal touch

There are a number of studies investigating CT-optimal touch, i.e., a touch that occurs with velocity of 3 cm/s, targets CT-fibers on the skin, and is commonly induced with some object in experimental laboratory settings. Hence, from a target person's perspective, the psychosocial context for receiving CT-optimal touches may be quite different from receiving human touches: during CT-optimal touch, the toucher and touched body region may not be visible and there may not be any other interpersonal communication between toucher and touched person (such as gaze or verbal communication). In this way, CT-optimal touch is typically received in a less natural interpersonal context than human touch. Next, we review studies examining responses to CT-optimal (object-induced) touch.

3.4.1. Subjective pleasantness

In general, there is accumulating evidence that a CT-optimal touch (i.e., an object-induced touch that is supposed to convey affective meanings) on the palm or forearm is experienced as more pleasant than a non-CT-optimal touch (Davidovic et al., 2016; Löken et al., 2011; Pawling et al., 2017; Portnova et al., 2020; Triscoli et al., 2017a,b). Importantly, however, several studies have implied that exposure to a CT-optimal touch or gentle stroking on the forearm is experienced as less pleasant *over repetitions* (Ree et al., 2020; Triscoli et al., 2014; Triscoli et al., 2017b). Consequently, it may possibly be that a "mechanically" conducted series of social touches may not always be positively experienced.

3.4.2. Behavioral responses

A number of studies have examined behavioral responses to CT-optimal touch in laboratory settings. It has been found that receiving repetitive CT-optimal touches or soft caresses on the arm in laboratory settings (*vs.* exposure to a control touch or no touch) does not increase prosociality in economic bargaining tasks (Rosenberger et al., 2018), and does not increase altruism in a charity-related task and does not reduce betrayal aversion in experimental tasks (Koppel et al., 2017). In addition, it has been found that receiving a CT-optimal touch (vs. non-CT-optimal touch) on the forearm in laboratory settings may not increase sensitivity to reward (Triscoli et al., 2017b). On the contrary, as described earlier in this review), studies in natural settings have found that *human* touch is related to increased prosocial behavior and compliance to requests (Guéguen and Fischer-Lokou, 2002, 2003; Joule and Guéguen, 2007). Hence, the findings suggest that a human touch in "natural settings" may increase prosociality more effectively than an object-induced touch in laboratory settings.

Importantly, during stress exposure, an object-induced CT-optimal touch may result in more positive responses. Specifically, two studies suggest that during stimulated heat pain, receiving CT-optimal touches on the forearm reduces experienced pain and anxious states and is experienced as more pleasant when compared to receiving a discriminative touch or no touch (Fidanza et al., 2021; Liljencrantz et al., 2017). This supports the view that also object-induced affective touch may have a bottom-up comforting function (i.e., it feels pleasant although it is not embedded in a natural interpersonal context).

3.4.3. Physiological responses

As was described earlier in this review, touch from a partner or friend during a physically or psychologically painful situation is found to predict lower physiological stress responses (Chatel-Goldman et al., 2014; Grewen et al., 2005; Triscoli et al., 2017a). In such cases, touch seems to have a comforting function. On the contrary, the evidence tentatively implies that object-induced CT-optimal touches (that occur without other interpersonal interaction) may not be related as consistent physiological responses as social touches occurring in natural interpersonal settings. That is, there is evidence that object-induced CT-optimal touches on the forearm in laboratory settings may reduce the transient arousal response (skin conductance amplitude) but not overall arousal state during the touching situation (skin conductance level), when compared to non-CT optimal touches (Etzi et al., 2018a,b). In addition, object-induced CT-optimal touches on the palm or forearm (vs. non-CT-optimal touches) in laboratory settings without being embedded with other interpersonal interaction may increase heart-rate variability and reduce heart rate deceleration but not reduce cortisol levels (Pawling et al., 2017; Triscoli et al., 2017b). Hence, physiological responses to CT-optimal touch have not been consistent.

3.4.4. Brain responses

A single study tentatively implied that exposure to an affective touch on the forearm (*vs.* non-affective touch or no touch) by a stranger in laboratory settings is related to decreased theta activity (von Mohr, Crowley, et al., 2018) that, in turn, is commonly interpreted to refer to lower relaxation or pleasantness. However, more brain studies are needed to make any conclusions on the topic.

Overall, most studies reviewed in this subsection have not directly compared object-induced CT-optimal touch to human touch. Nevertheless, comparison of the studies examining CT-optimal touch and studies examining human touch tentatively implies that responses to CT-optimal touch may possibly be less consistent and less positive than responses to human touch. However, in order to make any conclusions, there is a need for additional studies with direct experimental comparisons between behavioral and neural responses to human touch vs. CT-optimal touch.

3.5. Physical appearance of toucher

Not only familiarity vs. strangeness of toucher, but also physical appearance of toucher seems to play a crucial role for touch experience. In this context, original studies have focused either on facial expressions or physical attractiveness of toucher. Next, these studies are reviewed separately.

3.5.1. Facial expressions of toucher

3.5.1.1. Behavioral responses. Regarding pleasantness, there is evidence that smiling faces increase perceived pleasantness of a gentle social touch (CT-optimal touch) on the forearm (vs. frowning faces) (Ellingsen et al., 2014). Also, virtual-reality studies (where touch on the hand appears to come from a virtual character) have found that virtual character's touch and facial emotional expressions influence compliance to accept unfair offers in a virtual decision-making game (Harjunen et al., 2018; Spapé et al., 2019). Hence, facial emotions (especially negative emotions) appear to play a crucial role for subjective experience of social touch and in defining the behavioral consequences.

3.5.1.2. Brain responses. The modulatory influence of emotional facial expressions on touch perception is further supported by studies using electroencephalography (EEG). For example, toucher's facial emotions (anger, happiness, or sadness) were found to amplify somatosensory-evoked potentials (SEPs) as early as 25 ms after touch onset (Ravaja et al., 2017). In this study, touch stimulus was directed to the hand. The modulatory influence was also observed in late SEPs, of which amplitudes were stronger mainly by toucher's angry expression (Ravaja et al., 2017).

3.5.2. Physical attractiveness of toucher

Although temporary facial expressions of toucher may modify touch

experience, it seems that also more stable physical features, i.e., physical attractiveness, may modify target person's responses to social touch. Previous studies on this topic have not defined any "objective" criteria for attractiveness but relied on participants' subjective ratings.

Research evidence suggests that high attractiveness of toucher may increase experienced pleasantness of social touch exposure. First, a questionnaire-based study found that different types of touches are interpreted to convey more positive signals (e.g., trust, affection, receptivity) if the toucher is perceived as very attractive *vs.* not very attractive (Burgoon, 1991). In accordance with this, receiving a CT-optimal stroke on the arm and palm is found to result in more pleasant feelings and higher heart-rate variability (referring potentially to higher physiological relaxation) if the participants are simultaneously shown attractive vs. unattractive faces (Novembre et al., 2020). In addition, receiving touches on the shoulder and forearm during problem-solving discussion appears to be more positively experienced if the toucher is perceived to score high rather than low on attractiveness, status, and expertise (Burgoon et al., 1992). Moreover, receiving touch on the shoulder in a task-related situation is found to be experienced more positively if the toucher is highly attractive (Patterson et al., 1986). Taken together, studies conducted between the 1980 s–2020 s have consistently suggested that a similar sort of touch may be experienced very differently is toucher is perceived attractive vs. unattractive.

Finally, it is necessary to consider a single study indicating that social touch may increase experienced attractiveness of toucher (Boderman et al., 1972). Hence, more research is needed to make conclusions about the temporal relationships between experience of social touch and (perceived) attractiveness or likeability of the toucher.

3.6. Multimodal qualities of the environment

Consequently, toucher's physical appearance such as attractiveness and certain facial expressions modify pleasantness of touch experience. Interestingly, it has been found that also some human odors may make social contacts more rewarding for some individuals (Lübke et al., 2014). In the context of touch, no study has examined the role of human odors but there are pieces of evidence related to other types of odors.

Specifically, it has been found that social touch (CT-optimal touch) to dorsal forearm is experienced as less pleasant if subjects are simultaneously exposed to a disgusting odor (*vs.* not exposed to a disgusting odor) (Croy et al., 2014, 2016). Further, Croy's et al. (2016) study found that disgusting odors activate the orbitofrontal cortex and the amygdala and that the presence of disgusting odor is related to increased touch-induced fMRI activity (BOLD signal) in the somatosensory cortex and reduced activity in the insula (Croy et al., 2016). This implies that odors may modify immediate affective responses (such as hedonic processing) to social touch. Regarding visuo-tactile multimodality, a touch to the forearm is found to result in an altered amplitude of N100 if the subjects are simultaneously exposed to unpleasant affective pictures (when compared to neutral pictures) (Montoya and Sitges, 2006; Schirmer et al., 2011). This possibly implies that pictures may modify motivational relevance of touch exposure and, in that way, also enhance direction of attentional resources to touch. Further, a skin-to-skin touch on the forearm is experienced as more pleasant if simultaneously exposed to positive *vs.* negative pictures (Etzi et al., 2018a,b).

With regard to auditory factors, exposure to vocal sounds indicating surprise (vs. neutral or non-vocal sounds) is found to induce stronger auditory evoked potentials (P2 and late positive potential) when combined with exposure to stroking the arm (Schirmer and Gunter, 2017). Taken together, surrounding emotional cues from other sensory modalities may have a strong influence in the early perceptual processing of social touch.

3.7. Target person's attentiveness to social touch

Finally, the literature search obtained some studies related to target person's attentiveness to social touch. In one study, subjects were touched simultaneously when they were conducting either a simple cognitive task (e.g. verbal identification) or motor task (Gallace et al., 2010). It was found that sensitivity to another persons' touch (i.e. detection threshold to touch) was impaired during both tasks, especially during a motor task, possibly due to shared attentive resources between touch perception and task-related sensory-motor functioning (Gallace et al., 2010). In addition, demonstrating the fundamental role of attention in perceptual processing of touch, it has been reported that attended as compared to unattended touches on the wrist or finger may amplify somatosensory-evoked responses (N140 and P300) (Harjunen et al., 2017; Nakajima and Imamura, 2000).

Nevertheless, although attended and unattended exposures to social touch may be differently processed in the brain, a couple of studies suggest that attentiveness to social touch may not modulate the affective and behavioral consequences of being touched. For example, library customers touched on their palm by the library personnel (while lending a book) reported higher levels of liking toward the personnel and the library than those who were not touched, regardless of whether consciously noticing the touch or not (Fisher et al., 1976). In a similar way, women, who were requested to complete a questionnaire and either touched on their forearm or not, exhibited a similar Midas touch effect regardless of whether they observed the touch or not (Guéguen, 2002). Taken together, attentiveness to social touch may modulate perceptional sensitivity to touch but not affective or behavioral responses to social touch.

On the other hand, an fMRI study showed that CT- and non-CT-optimal touches on the forearm may similarly deactivate the default mode network when there are no strong competitive stimuli in the environment (Strauss et al., 2019). As the default mode network (DMN) is activated especially during rest and mind-wandering (Mak et al., 2017), the findings indicate appears that touch (whether social or impersonal touch) may likely grasp one's attention if there are no competitive stimuli. However, when attention is particularly directed to touch, it appears to particularly strongly deactivate the DMN. That is, when directing attention to touch exposure, touch on the hand reduces connections of the posterior cingulate cortex (i.e. a central region of the DMN) with the insula and inferior frontal gyrus (when compared to situations when attention is directed to auditory stimuli) (Cerritelli et al., 2017). Hence, directing attention to touch may enhance processing of social and interoceptive aspects of touch exposure.

4. Main findings

In summary, this study identified a variety of psychosocial and situational factors and toucher's characteristics that modulate the immediate experiences and responses to social touch. The factors are summarized in Fig. 3. Depending of an array of contextual factors, the same caress is not necessarily experienced as pleasant and may not have potential long-term positive effects of touch, including e.g. oxytocin release (Portnova et al., 2020) and reduced stress reactivity (Lee and Cichy, 2020). Hence, if aiming to produce pleasant touch experiences, it is necessary to adjust psychosocial situational factors carefully so that, as likely as possible, touch would be experienced as secure, appropriate, and pleasant.

In order to produce pleasant touch experiences, social touch could be utilized at a certain level of acquaintanceship (not in the first meeting but later meetings). Secondly, since other than family members are allowed to touch only 20 % of the body (primarily hands) (Suvilehto et al., 2015, 2019), touch could be directed to a restricted body region such as hands. Thirdly, the evidence tentatively suggests that touch may more likely be experienced as pleasant if it occurs in a natural context in a situationally appropriate way (e.g., a touch between a health-care professional and a patient or a touch that is embedded with other social interaction), whereas repetitive touches in laboratory settings may not necessarily be experienced positively. Fourth, it seems that receiving

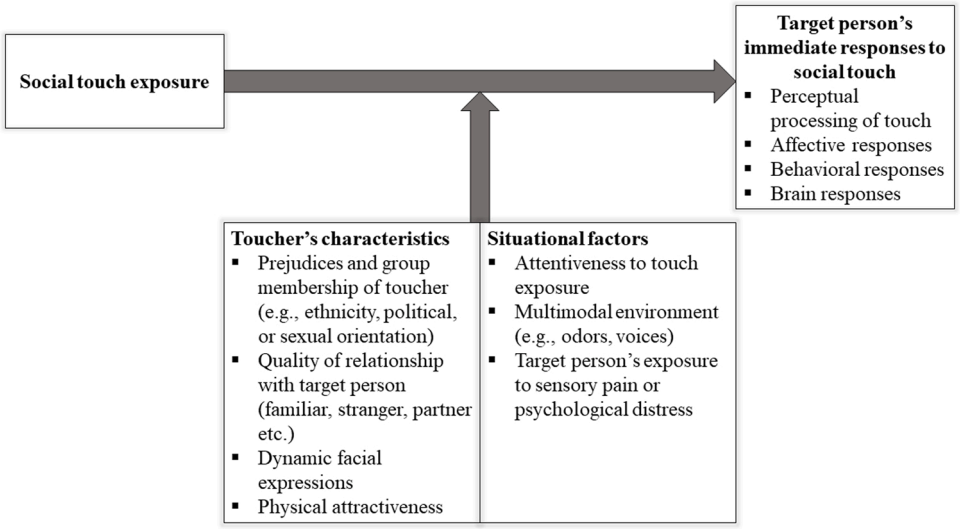

Fig. 3. A summary of the psychosocial contextual factors modulating responses to social touch exposure.

touch (both from familiar people and strangers) is experienced as more pleasant if the target person is experiencing sensory pain or psychological distress, supporting comforting functions of touch. Finally, attention could be paid to ecological validity of the findings: many touch-related experiments have been conducted in formal (laboratory) settings where there may be, for example, some unexpected unpleasant odors that, in turn, are found to affect touch experience negatively. Overall, adjusting these situational factors during touch exposure could increase likelihood that social touch could produce positive responses in target person.

5. Methodological considerations

Before considering implications of this review, it is necessary to consider certain methodological issues. Firstly, the focus of this review was restricted to studies conducted in non-clinical adult populations. Since age and neuropsychiatric symptoms may affect experience of touch exposure (Crucianelli et al., 2016; Sehlstedt et al., 2016), our results cannot be directly generalized to child populations or clinical populations. Secondly, most studies were correlational by nature. Hence, the temporal or causal relationships between touch experience and contextual factors cannot be firmly concluded. For example, it can be speculated that exposure to touch may also affect perception of toucher's facial emotions. Finally, this review focused on the influences of social touch on *target person's* responses. Hence, the results cannot be generalized to *toucher's* experience of social touch event.

It is necessary to consider that this review included a comparatively heterogeneous combination of original studies. That is, there were observational studies conducted in natural settings (e.g., in a library or university campus), experimental studies in laboratory settings, and questionnaire-based studies in every-day life investigating the modifying roles of psychosocial contextual factors on touch experiences. The heterogeneity of previously adopted research methods has been a challenge also in previous reviews, as each method includes different limitations (Hertenstein and Keltner, 2011). Therefore, although our broad scope of studies included many strengths, it also included a limitation that a systematic comparison of the outcomes and measures was not possible as the outcomes are not directly comparable with each other.

Moreover, the original studies included a variety of different types of touches, ranging from hand-holding to a gentle caress on the forearm, a pat on the shoulder, and hugging. Also, some original studies did not specify either the body region where touch was directed to or the type of touch under investigation. This further complicated a systematic comparison of the findings because it is known that different types of touches convey different affective and interpersonal meanings (Thompson and Hampton, 2011). Moreover, the studies were conducted in different countries, and cultural factors are known to affect the use of touch in social interactions and touch experiences. However, the roles of sensory features of touch (Taneja et al., 2021) and cultural factors (Sorokowska et al., 2021) for touch experience have been reviewed previously. Hence, we decided not to review those issues in this paper but to focus on the modifying roles of psychosocial contextual factors on touch experience that have not been reviewed before.

6. Implications for research

The implications for research are summarized in Fig. 4. In several studies, hypotheses about positive effects of social touch have not been supported (Edens et al., 1992; Guéguen et al., 2011; Rosenberger et al., 2018; Williams and Kleinke, 1993). One explanation for this may be specific contextual factors that have not been taken into consideration and have modulated subjective experience of social touch. For example, in a number of studies, touch exposure has not been embedded into a natural social interaction (including also other social cues besides of touch) or has been conducted by a stranger. Also, physical attractiveness of toucher (Novembre et al., 2020) and accompanied emotional expressions (Ravaja et al., 2017) may play strong roles for touch experience but have not been considered in many studies. In the contrast, some studies have paid careful attention to adjustment of such contextual factors that may not crucially influence subjective experience of social touch. For example, attentiveness to touch exposure (i.e. whether the subjects have vision on the body region that is touched) is commonly carefully adjusted but may not always have crucial effects on behavioral responses to touch exposure (e.g. compliance to toucher's requests) (Guéguen, 2002).

This review points out that a variety of brain regions are involved in processing of contextual cues and social touch. Several fMRI studies, however, have investigated touch-induced responses using a comparatively narrow set of regions-of-interest (ROIs) (Kraus et al., 2019). Hence, voxel-wise analyses or a comprehensive set of ROIs could provide novel perspectives to neural touch processing. Moreover, as self-reports of emotional states include their strengths and weaknesses, future studies could more widely utilize multi-voxel pattern analysis as a complementary method to decode the emotional states of experimental subjects (Saarimäki et al., 2018, 2016). In this way, emotional reactions

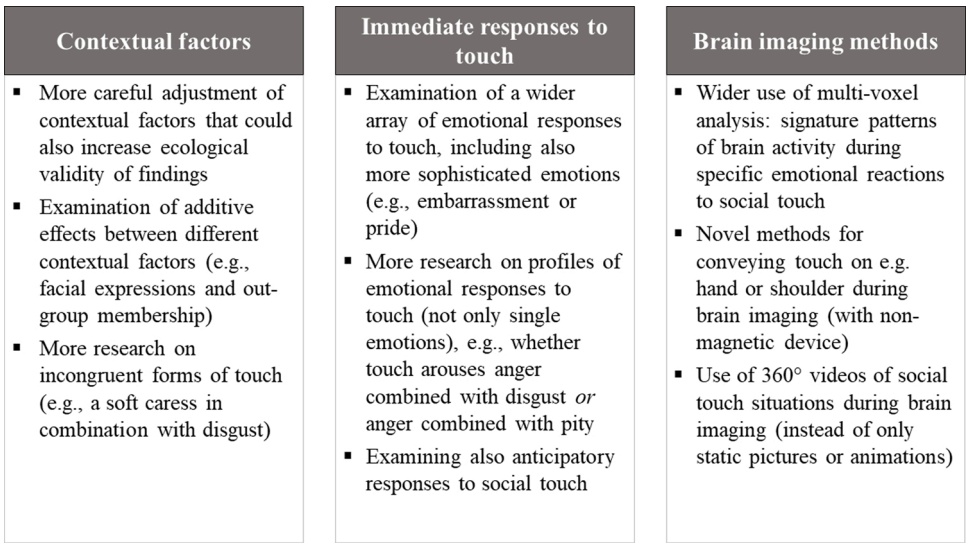

Fig. 4. A summary of the research implications of this review.

to touch could be directly assessed based on signature patterns of brain activity that can be obtained during specific emotional states. This would be especially feasible in such experiments where participants would likely have self-reporting biases. In addition, there is evidence for anticipatory responses in the prefrontal and parietal cortex that adjust later phases of touch processing in a top-down manner (Carlsson et al., 2000). More attention could be paid to the anticipatory responses to social touch.

Currently, there are studies utilizing touch in the context of functional magnetic resonance (fMRI) measurements (Kraus et al., 2019; Morese et al., 2019; Reddan et al., 2020; Strauss et al., 2019), but there is a need for novel methods that could convey touch more practically during brain imaging where a non-magnetic apparatus is needed. Commonly, touch has been applied on the subjects' leg (Kreuder et al., 2017). However, the generalizability of such results may be restricted because touch on different body parts is known to convey different signals (Lee and Guerrero, 2001). Other studies have used, for example, a tactile glove for touch exposure (Harjunen et al., 2018) or an "air--pressure-driven oscillation compression sleeve" that was experienced as pleasant and activated overlapping brain regions than CT-optimal touch (Case et al., 2020). Overall, novel methods are needed to make touch exposure more practical in fMRI studies.

Most studies have restricted their investigations on touched-induced disgust or comfort, although social touch can arouse a wide variety of emotions (anger, disgust, fear, gratitude, harassment, formality, happiness, love, sadness, sympathy, embarrassment, envy, pride, or surprise) (J. W. Lee and Guerrero, 2001; Thompson and Hampton, 2011). For example, there is evidence that different out-groups elicit different profiles of affective reactions: gay men may arouse strong feelings of disgust and pity, whereas African Americans may elicit feelings of pity and fear (Cottrell and Neuberg, 2005). Thus, besides of examining *single emotions*, also further studies on *emotional profiles* elicited by social touch are needed.

Additionally, more studies are needed whether there are additive and interactive effects between different contextual factors. For example, more studies are needed whether an angry facial emotion together with a minority status or criminal history produces stronger immediate responses in target person than any single contextual factor. Also, there is evidence that social touch (Nummenmaa et al., 2016) and social laughter (Manninen et al., 2017) modulate the endogenous opioid system. It may be that exposure to both social touch and social laughter could have especially strong effects on the brain opioid system, but more research is needed. This could also improve generalizability of the findings to every-day environments: every-day social touch situations typically include an array of simultaneously varying contextual factors.

Finally, future research should provide evidence regarding the association between neural, physiological, behavioral, and self-reported measures related to social touch. This would facilitate interpretation of findings and increase understanding of partly inconclusive findings of studies using different methodological approaches. It seems that, for example, high pleasantness of touch is related to comparable physiological responses such as reduced heart rate (Triscoli et al., 2017a) and also reward-related responses in the brain such as increased μ-opioid receptor availability (Nummenmaa et al., 2016), but more research is needed on the connections between different measures.

7. Conclusions

In summary, this review found that pleasantness of touch exposure may be modified by a variety of contextual psychosocial factors such as toucher's characteristics (e.g. facial expressions, stage of acquaintanceship with the target person, and out-group membership) and situational factors (e.g. target person's situational distress or pain). Consequently, when planning touch-based interventions and research designs, the context where exposure to social touch occurs should be carefully designed based on existing empirical evidence.

Declaration of Competing Interest

The authors report no financial relationships with commercial interests.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.neubiorev.2021.09.027.

References

Allport, G.W., Pettigrew, T., 1954. The Nature of Prejudice.

Anderson, J.G., Taylor, A.G., 2011. Effects of healing touch in clinical practice: a systematic review of randomized clinical trials. J. Holist Nurs. 29 (3), 221–228. https://doi.org/10.1177/0898010110393353.

Beßler, R., Bendas, J., Sailer, U., Croy, I., 2020. The "Longing for Interpersonal Touch Picture Questionnaire": development of a new measurement for touch perception. Int. J. Psychol. 55 (3), 446–455. https://doi.org/10.1002/ijop.12616.

Boderman, A., Freed, D.W., Kinnucan, M.T., 1972. Touch-me, like-me- testing an encounter group assumption. J. Appl. Behav. Sci. 8 (5) https://doi.org/10.1177/002188637200800503, 527-&.

Burgoon, J.K., 1991. Relational message interpretations of touch, conversational distance, and posture. J. Nonverbal Behav. 15 (4), 233–259. https://doi.org/10.1007/bf00986924.

Burgoon, J.K., Walther, J.B., Baesler, E.J., 1992. Interpretations, evaluations, and consequences of interpersonal touch. Hum. Commun. Res. 19 (2), 237–263. https://doi.org/10.1111/j.1468-2958.1992.tb00301.x.

Camps, J., Tuteleers, C., Stouten, J., Nelissen, J., 2013. A situational touch: how touch affects people's decision behavior. Soc. Influ. 8 (4), 237–250. https://doi.org/10.1080/15534510.2012.719479.

Carlsson, K., Petrovic, P., Skare, S., Petersson, K.M., Ingvar, M., 2000. Tickling expectations: neural processing in anticipation of a sensory stimulus. J. Cogn. Neurosci. 12 (4), 691–703. https://doi.org/10.1162/089892900562318.

Cascio, C.J., Moore, D., McGlone, F., 2019. Social touch and human development. Dev. Cogn. Neurosci. 35, 5–11. https://doi.org/10.1016/j.dcn.2018.04.009.

Case, L.K., Čeko, M., Gracely, J.L., Richards, E.A., Olausson, H., Bushnell, M.C., 2016. Touch perception altered by chronic pain and by opioid blockade. eNeuro 3 (1). https://doi.org/10.1523/eneuro.0138-15.2016.

Case, L.K., Liljencrantz, J., McCall, M.V., Bradson, M., Necaise, A., Tubbs, J., et al., 2020. Pleasant deep pressure: expanding the social touch hypothesis. Neuroscience. https://doi.org/10.1016/j.neuroscience.2020.07.050.

Cerritelli, F., Chiacchiaretta, P., Gambi, F., Ferretti, A., 2017. Effect of continuous touch on brain functional connectivity is modified by the operator's tactile attention. Front. Hum. Neurosci. 11, 368. https://doi.org/10.3389/fnhum.2017.00368.

Chatel-Goldman, J., Congedo, M., Jutten, C., Schwartz, J.L., 2014. Touch increases autonomic coupling between romantic partners. Front. Behav. Neurosci. 8, 95. https://doi.org/10.3389/fnbeh.2014.00095.

Choma, B.L., Charlesford, J.J., Hodson, G., 2018. Reducing prejudice with (elaborated) imagined and physical intergroup contact interventions. Current Research in Social Psychology. University of Iowa.

Coan, J.A., Schaefer, H.S., Davidson, R.J., 2006. Lending a hand: social regulation of the neural response to threat. Psychol. Sci. 17 (12), 1032–1039. https://doi.org/10.1111/j.1467-9280.2006.01832.x.

Cottrell, C.A., Neuberg, S.L., 2005. Different emotional reactions to different groups: a sociofunctional threat-based approach to "prejudice". J. Pers. Soc. Psychol. 88 (5), 770–789. https://doi.org/10.1037/0022-3514.88.5.770.

Croy, I., Angelo, S.D., Olausson, H., 2014. Reduced pleasant touch appraisal in the presence of a disgusting odor. PLoS One 9 (3), e92975. https://doi.org/10.1371/journal.pone.0092975.

Croy, I., Drechsler, E., Hamilton, P., Hummel, T., Olausson, H., 2016. Olfactory modulation of affective touch processing - A neurophysiological investigation. Neuroimage 135, 135–141. https://doi.org/10.1016/j.neuroimage.2016.04.046.

Crucianelli, L., Cardi, V., Treasure, J., Jenkinson, P.M., Fotopoulou, A., 2016. The perception of affective touch in anorexia nervosa. Psychiatry Res. 239, 72–78. https://doi.org/10.1016/j.psychres.2016.01.078.

Crusco, A.H., Wetzel, C.G., 1984. The Midas touch - the effects of interpersonal touch on restaurant tipping. Pers. Soc. Psychol. Bull. 10 (4), 512–517. https://doi.org/10.1177/0146167284104003.

Davidovic, M., Jönsson, E.H., Olausson, H., Björnsdotter, M., 2016. Posterior superior temporal sulcus responses predict perceived pleasantness of skin stroking. Front. Hum. Neurosci. 10, 432. https://doi.org/10.3389/fnhum.2016.00432.

Debrot, A., Schoebi, D., Perrez, M., Horn, A.B., 2013. Touch as an interpersonal emotion regulation process in couples' daily lives: the mediating role of psychological intimacy. Pers. Soc. Psychol. Bull. 39 (10), 1373–1385. https://doi.org/10.1177/0146167213497592.

Delgado, M.R., 2007. Reward-related responses in the human striatum. Ann. N. Y. Acad. Sci. 1104, 70–88. https://doi.org/10.1196/annals.1390.002.

Ditzen, B., Neumann, I.D., Bodenmann, G., von Dawans, B., Turner, R.A., Ehlert, U., Heinrichs, M., 2007. Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. Psychoneuroendocrinology 32 (5), 565–574. https://doi.org/10.1016/j.psyneuen.2007.03.011.

Dolinski, D., 2010. Touch, compliance, and homophobia. J. Nonverbal Behav. 34 (3), 179–192. https://doi.org/10.1007/s10919-010-0090-1.

Drescher, V.M., Whitehead, W.E., Morrill-Corbin, E.D., Cataldo, M.F., 1985. Physiological and subjective reactions to being touched. Psychophysiology 22 (1), 96–100. https://doi.org/10.1111/j.1469-8986.1985.tb01565.x.

Ebisch, S.J., Ferri, F., Gallese, V., 2014. Touching moments: desire modulates the neural anticipation of active romantic caress. Front. Behav. Neurosci. 8, 60. https://doi.org/10.3389/fnbeh.2014.00060.

Edens, J.L., Larkin, K.T., Abel, J.L., 1992. The effect of social support and physical touch on cardiovascular reactions to mental stress. J. Psychosom. Res. 36 (4), 371–381. https://doi.org/10.1016/0022-3999(92)90073-b.

Ellingsen, D.M., Wessberg, J., Chelnokova, O., Olausson, H., Laeng, B., Leknes, S., 2014. In touch with your emotions: oxytocin and touch change social impressions while others' facial expressions can alter touch. Psychoneuroendocrinology 39, 11–20. https://doi.org/10.1016/j.psyneuen.2013.09.017.

Ellingsen, D.M., Leknes, S., Løseth, G., Wessberg, J., Olausson, H., 2015. The neurobiology shaping affective touch: expectation, motivation, and meaning in the multisensory context. Front. Psychol. 6, 1986. https://doi.org/10.3389/fpsyg.2015.01986.

Emmers, T.M., Dindia, K., 1995. The effect of relational stage and intimacy on touch - an extension of Guerrero and Andersen. Pers. 2 (3), 225–236. https://doi.org/10.1111/j.1475-6811.1995.tb00088.x.

Erceau, D., Guéguen, N., 2007. Tactile contact and evaluation of the toucher. J. Soc. Psychol. 147 (4), 441–444. https://doi.org/10.3200/socp.147.4.441-444.

Etzi, R., Carta, C., Gallace, A., 2018a. Stroking and tapping the skin: behavioral and electrodermal effects. Exp. Brain Res. 236 (2), 453–461. https://doi.org/10.1007/s00221-017-5143-9.

Etzi, R., Zampini, M., Juravle, G., Gallace, A., 2018b. Emotional visual stimuli affect the evaluation of tactile stimuli presented on the arms but not the related electrodermal responses. Exp. Brain Res. 236 (12), 3391–3403. https://doi.org/10.1007/s00221-018-5386-0.

Fidanza, F., Polimeni, E., Pierangeli, V., Martini, M., 2021. A better touch: C-tactile fibers related activity is associated to pain reduction during temporal summation of second pain. J. Pain. https://doi.org/10.1016/j.jpain.2021.01.001.

Field, T., 2010. Touch for socioemotional and physical well-being: a review. Dev. Rev. 30 (4), 367–383. https://doi.org/10.1016/j.dr.2011.01.001.

Fisher, J.D., Rytting, M., Heslin, R., 1976. Hands touching hands: affective and evaluative effects of an interpersonal touch. Sociometry 39 (4), 416–421.

Floyd, K., 2000. Affectionate same-sex touch: the influence of homophobia on observers' perceptions. J. Soc. Psychol. 140 (6), 774–788. https://doi.org/10.1080/00224540009600516.

Gallace, A., Spence, C., 2010. The science of interpersonal touch: an overview. Neurosci. Biobehav. Rev. 34 (2), 246–259. https://doi.org/10.1016/j.neubiorev.2008.10.004.

Gallace, A., Zeeden, S., Röder, B., Spence, C., 2010. Lost in the move? Secondary task performance impairs tactile change detection on the body. Conscious. Cogn. 19 (1), 215–229. https://doi.org/10.1016/j.concog.2009.07.003.

Gazzola, V., Spezio, M.L., Etzel, J.A., Castelli, F., Adolphs, R., Keysers, C., 2012. Primary somatosensory cortex discriminates affective significance in social touch. Proc. Natl. Acad. Sci. U. S. A. 109 (25), E1657–1666. https://doi.org/10.1073/pnas.1113211109.

Gladney, K., Barker, L., 1979. The effects of tactile history on attitudes toward and frequency of touching behavior. Sign Lang. Stud. 24, 231–252.

Gliga, T., Farroni, T., Cascio, C.J., 2019. Social touch: A new vista for developmental cognitive neuroscience? Dev. Cogn. Neurosci. 35, 1–4. https://doi.org/10.1016/j.dcn.2018.05.006.

Goldman, M., Kiyohara, O., Pfannensteil, D.A., 1985. Interpersonal touch, social labeling, and the foot-in-the-door effect. J. Soc. Psychol. 125 (2), 143–147. https://doi.org/10.1080/00224545.1985.9922866.

Goldstein, P., Shamay-Tsoory, S.G., Yellinek, S., Weissman-Fogel, I., 2016. Empathy predicts an experimental pain reduction during touch. J. Pain 17 (10), 1049–1057. https://doi.org/10.1016/j.jpain.2016.06.007.

Goldstein, P., Weissman-Fogel, I., Shamay-Tsoory, S.G., 2017. The role of touch in regulating inter-partner physiological coupling during empathy for pain. Sci. Rep. 7 (1), 3252. https://doi.org/10.1038/s41598-017-03627-7.

Goldstein, P., Weissman-Fogel, I., Dumas, G., Shamay-Tsoory, S.G., 2018. Brain-to-brain coupling during handholding is associated with pain reduction. Proc. Natl. Acad. Sci. U. S. A. 115 (11), E2528–e2537. https://doi.org/10.1073/pnas.1703643115.

Grewen, K.M., Anderson, B.J., Girdler, S.S., Light, K.C., 2003. Warm partner contact is related to lower cardiovascular reactivity. Behav. Med. 29 (3), 123–130. https://doi.org/10.1080/08964280309596065.

Grewen, K.M., Girdler, S.S., Amico, J., Light, K.C., 2005. Effects of partner support on resting oxytocin, cortisol, norepinephrine, and blood pressure before and after warm partner contact. Psychosom. Med. 67 (4), 531–538. https://doi.org/10.1097/01.psy.0000170341.88395.47.

Guéguen, N., 2002. Touch, awareness of touch, and compliance with a request. Percept. Mot. Skills 95 (2), 355–360. https://doi.org/10.2466/pms.2002.95.2.355.

Guéguen, N., Fischer-Lokou, J., 2002. An evaluation of touch on a large request: a field setting. Psychol. Rep. 90 (1), 267–269. https://doi.org/10.2466/pr0.2002.90.1.267.

Guéguen, N., Fischer-Lokou, J., 2003. Another evaluation of touch and helping behavior. Psychol. Rep. 92 (1), 62–64. https://doi.org/10.2466/pr0.2003.92.1.62.

Guéguen, N., Afifi, F., Brault, S., Charles-Sire, V., Leforestier, P.M., Morzedec, A., Piron, E., 2011. Failure of tactile contact to increase request compliance: the case of blood donation behavior. J. Articles Support Null Hypothesis (8), 1–8.

Guerrero, L.K., Andersen, P.A., 1991. The waxing and waning of relational intimacy - touch as a function of relational stage, gender and touch avoidance. J. Soc. Pers. Relat. 8 (2), 147–165. https://doi.org/10.1177/0265407591082001.

Harjunen, V.J., Ahmed, I., Jacucci, G., Ravaja, N., Spapé, M.M., 2017. Manipulating bodily presence affects cross-modal spatial attention: a virtual-reality-Based ERP study. Front. Hum. Neurosci. 11, 79. https://doi.org/10.3389/fnhum.2017.00079.

Harjunen, V.J., Spape, M., Ahmed, I., Jacucci, G., Ravaja, N., 2018. Persuaded by the machine: the effect of virtual nonverbal cues and individual differences on compliance in economic bargaining. Comput. Human Behav. 87, 384–394. https://doi.org/10.1016/j.chb.2018.06.012.

Henley, N.M., 1973. Status and sex - some touching observations. Bull. Psychon. Soc. 2 (2), 91–93. https://doi.org/10.3758/bf03327726.

Hertenstein, M.J., Keltner, D., 2011. Gender and the Communication of Emotion Via Touch. Sex Roles 64 (1-2), 70–80. https://doi.org/10.1007/s11199-010-9842-y.

Hornik, J., Ellis, S., 1988. Strategies to secure compliance for a mall intercept interview. Public Opin. Q. 52 (4), 539–551. https://doi.org/10.1086/269129.

Joule, R.V., Guéguen, N., 2007. Touch, compliance, and awareness of tactile contact. Percept. Mot. Skills 104 (2), 581–588. https://doi.org/10.2466/pms.104.2.581-588.
Kirsch, L.P., Krahé, C., Blom, N., Crucianelli, L., Moro, V., Jenkinson, P.M., Fotopoulou, A., 2018. Reading the mind in the touch: neurophysiological specificity in the communication of emotions by touch. Neuropsychologia 116 (Pt A), 136–149. https://doi.org/10.1016/j.neuropsychologia.2017.05.024.
Koole, S.L., Sin, M.T.A., Schneider, I.K., 2014. Embodied terror management: interpersonal touch alleviates existential concerns among individuals with low self-esteem. Psychol. Sci. 25 (1), 30–37. https://doi.org/10.1177/0956797613483478.
Koppel, L., Andersson, D., Morrison, I., Vastfjall, D., Tinghog, G., 2017. The (Null) effect of affective touch on betrayal aversion, altruism, and risk taking. Front. Behav. Neurosci. 11 https://doi.org/10.3389/fnbeh.2017.00251.
Korisky, A., Eisenberger, N.I., Nevat, M., Weissman-Fogel, I., Shamay-Tsoory, S.G., 2020. A dual-brain approach for understanding the neuralmechanisms that underlie the comforting effects of social touch. Cortex 127, 333–346. https://doi.org/10.1016/j.cortex.2020.01.028.
Kraus, J., Frick, A., Roman, R., Jurkovicova, L., Marecek, R., Mikl, M., et al., 2019. Soothing the emotional brain: modulation of neural activity to personal emotional stimulation by social touch. Soc. Cogn. Affect. Neurosci. 14 (11), 1179–1185. https://doi.org/10.1093/scan/nsz090.
Kraus, J., Roman, R., Lacinová, L., Lamoš, M., Brázdil, M., Fredrikson, M., 2020. Imagery-induced negative affect, social touch and frontal EEG power band activity. Scand. J. Psychol. 61 (6), 731–739. https://doi.org/10.1111/sjop.12661.
Kreuder, A.K., Scheele, D., Wassermann, L., Wollseifer, M., Stoffel-Wagner, B., Lee, M.R., et al., 2017. How the brain codes intimacy: the neurobiological substrates of romantic touch. Hum. Brain Mapp. 38 (9), 4525–4534. https://doi.org/10.1002/hbm.23679.
Kringelbach, M.L., 2005. The human orbitofrontal cortex: linking reward to hedonic experience. Nat. Rev. Neurosci. 6 (9), 691–702. https://doi.org/10.1038/nrn1747.
Kurzban, R., 2001. The social psychophysics of cooperation: nonverbal communication in a public goods game. J. Nonverbal Behav. 25 (4), 241–259. https://doi.org/10.1023/a:1012563421824.
Lee, J.E., Cichy, K.E., 2020. Complex role of touch in social relationships for older adults' cardiovascular disease risk. Res. Aging 42 (7–8), 208–216. https://doi.org/10.1177/0164027520915793.
Lee, J.W., Guerrero, L.K., 2001. Types of touch in cross-sex relationships between coworkers: perceptions of relational and emotional messages, inappropriateness, and sexual harassment. J. Appl. Commun. Res. 29 (3), 197–220. https://doi.org/10.1080/00909880128110.
Levav, J., Argo, J.J., 2010. Physical contact and financial risk taking. Psychol. Sci. 21 (6), 804–810. https://doi.org/10.1177/0956797610369493.
Liljencrantz, J., Strigo, I., Ellingsen, D.M., Krämer, H.H., Lundblad, L.C., Nagi, S.S., et al., 2017. Slow brushing reduces heat pain in humans. Eur. J. Pain 21 (7), 1173–1185. https://doi.org/10.1002/ejp.1018.
Löken, L.S., Evert, M., Wessberg, J., 2011. Pleasantness of touch in human glabrous and hairy skin: order effects on affective ratings. Brain Res. 1417, 9–15. https://doi.org/10.1016/j.brainres.2011.08.011.
Long, Y., Zheng, L., Zhao, H., Zhou, S., Zhai, Y., Lu, C., 2021. Interpersonal neural synchronization during interpersonal touch underlies affiliative pair bonding between romantic couples. Cereb. Cortex 31 (3), 1647–1659. https://doi.org/10.1093/cercor/bhaa316.
Lübke, K.T., Croy, I., Hoenen, M., Gerber, J., Pause, B.M., Hummel, T., 2014. Does human body odor represent a significant and rewarding social signal to individuals high in social openness? PLoS One 9 (4), e94314. https://doi.org/10.1371/journal.pone.0094314.
Major, B., Schmidlin, A.M., Williams, L., 1990. Gender patterns in social touch - the impact of setting and age. J. Pers. Soc. Psychol. 58 (4), 634–643. https://doi.org/10.1037/0022-3514.58.4.634.
Mak, L.E., Minuzzi, L., MacQueen, G., Hall, G., Kennedy, S.H., Milev, R., 2017. The default mode network in healthy individuals: a systematic review and meta-analysis. Brain Connect. 7 (1), 25–33. https://doi.org/10.1089/brain.2016.0438.
Manninen, S., Tuominen, L., Dunbar, R.I., Karjalainen, T., Hirvonen, J., Arponen, E., et al., 2017. Social laughter triggers endogenous opioid release in humans. J. Neurosci. 37 (25), 6125–6131. https://doi.org/10.1523/jneurosci.0688-16.2017.
Martin, B.A.S., 2012. A stranger's touch: effects of accidental interpersonal touch on consumer evaluations and shopping time. J. Consum. Res. 39 (1), 174–184. https://doi.org/10.1086/662038.
Massaccesi, C., Korb, S., Skoluda, N., Nater, U.M., Silani, G., 2020. Effects of Appetitive and aversive motivational states on wanting and liking of interpersonal touch. Neuroscience. https://doi.org/10.1016/j.neuroscience.2020.09.025.
Montoya, P., Sitges, C., 2006. Affective modulation of somatosensory-evoked potentials elicited by tactile stimulation. Brain Res. 1068 (1), 205–212. https://doi.org/10.1016/j.brainres.2005.11.019.
Morese, R., Lamm, C., Bosco, F.M., Valentini, M.C., Silani, G., 2019. Social support modulates the neural correlates underlying social exclusion. Soc. Cogn. Affect. Neurosci. 14 (6), 633–643. https://doi.org/10.1093/scan/nsz033.
Murphy, M.L.M., Janicki-Deverts, D., Cohen, S., 2018. Receiving a hug is associated with the attenuation of negative mood that occurs on days with interpersonal conflict. PLoS One 13 (10), e0203522. https://doi.org/10.1371/journal.pone.0203522.
Nakajima, Y., Imamura, N., 2000. Relationships between attention effects and intensity effects on the cognitive N140 and P300 components of somatosensory ERPs. Clin. Neurophysiol. 111 (10), 1711–1718. https://doi.org/10.1016/s1388-2457(00)00383-7.
Nilsen, W.J., Vrana, S.R., 1998. Some touching situations: the relationship between gender and contextual variables in cardiovascular responses to human touch. Ann. Behav. Med. 20 (4), 270–276. https://doi.org/10.1007/bf02886376.
Novembre, G., Etzi, R., Morrison, I., 2020. Hedonic Responses to Touch are Modulated by the Perceived Attractiveness of the Caresser. Neuroscience. https://doi.org/10.1016/j.neuroscience.2020.10.007.
Nummenmaa, L., Tuominen, L., Dunbar, R., Hirvonen, J., Manninen, S., Arponen, E., et al., 2016. Social touch modulates endogenous μ-opioid system activity in humans. Neuroimage 138, 242–247. https://doi.org/10.1016/j.neuroimage.2016.05.063.
Park, J.H., van Leeuwen, F., Chochorelou, Y., 2013. Disease-avoidance processes and stigmatization: cues of substandard health arouse heightened discomfort with physical contact. J. Soc. Psychol. 153 (2), 212–228. https://doi.org/10.1080/00224545.2012.721812.
Patterson, M.L., Powell, J.L., Lenihan, M.G., 1986. Touch, compliance, and interpersonal affect. J. Nonverbal Behav. 10 (1), 41–50. https://doi.org/10.1007/bf00987204.
Pawling, R., Cannon, P.R., McGlone, F.P., Walker, S.C., 2017. C-tactile afferent stimulating touch carries a positive affective value. PLoS One 12 (3), e0173457. https://doi.org/10.1371/journal.pone.0173457.
Phelan, J.E., 2009. Exploring the use of touch in the psychotherapeutic setting: a phenomenological review. Psychotherapy (Chic) 46 (1), 97–111. https://doi.org/10.1037/a0014751.
Pisano, M.D., Wall, S.M., Foster, A., 1986. Perceptions of nonreciprocal touch in romantic relationships. J. Nonverbal Behav. 10, 29–40.
Portnova, G.V., Proskurnina, E.V., Sokolova, S.V., Skorokhodov, I.V., Varlamov, A.A., 2020. Perceived pleasantness of gentle touch in healthy individuals is related to salivary oxytocin response and EEG markers of arousal. Exp. Brain Res. 238 (10), 2257–2268. https://doi.org/10.1007/s00221-020-05891-y.
Ravaja, N., Harjunen, V., Ahmed, I., Jacucci, G., Spapé, M.M., 2017. Feeling touched: emotional modulation of somatosensory potentials to interpersonal touch. Sci. Rep. 7, 40504. https://doi.org/10.1038/srep40504.
Reddan, M.C., Young, H., Falkner, J., López-Solà, M., Wager, T.D., 2020. Touch and social support influence interpersonal synchrony and pain. Soc. Cogn. Affect. Neurosci. 15 (10), 1064–1075. https://doi.org/10.1093/scan/nsaa048.
Ree, A., Bendas, J., Pabel, L., Croy, I., Sailer, U., 2020. Right between the eyes: corrugator muscle activity tracks the changing pleasantness of repeated slow stroking touch. Physiol. Behav. 222, 112903 https://doi.org/10.1016/j.physbeh.2020.112903.
Rilling, J.K., Dagenais, J.E., Goldsmith, D.R., Glenn, A.L., Pagnoni, G., 2008. Social cognitive neural networks during in-group and out-group interactions. Neuroimage 41 (4), 1447–1461. https://doi.org/10.1016/j.neuroimage.2008.03.044.
Robinson, K.J., Hoplock, L.B., Cameron, J.J., 2015. When in doubt, reach out: touch is a covert but effective mode of soliciting and providing social support. Soc. Psychol. Personal. Sci. 6 (7), 831–839. https://doi.org/10.1177/1948550615584197.
Rosenberger, L.A., Ree, A., Eisenegger, C., Sailer, U., 2018. Slow touch targeting CT-fibres does not increase prosocial behaviour in economic laboratory tasks. Sci. Rep. 8 (1), 7700. https://doi.org/10.1038/s41598-018-25601-7.
Russo, V., Ottaviani, C., Spitoni, G.F., 2020. Affective touch: a meta-analysis on sex differences. Neurosci. Biobehav. Rev. 108, 445–452. https://doi.org/10.1016/j.neubiorev.2019.09.037.
Saarimäki, H., Gotsopoulos, A., Jääskeläinen, I.P., Lampinen, J., Vuilleumier, P., Hari, R., et al., 2016. Discrete neural signatures of basic emotions. Cereb. Cortex 26 (6), 2563–2573. https://doi.org/10.1093/cercor/bhv086.
Saarimäki, H., Ejtehadian, L.F., Glerean, E., Jääskeläinen, I.P., Vuilleumier, P., Sams, M., Nummenmaa, L., 2018. Distributed affective space represents multiple emotion categories across the human brain. Soc. Cogn. Affect. Neurosci. 13 (5), 471–482. https://doi.org/10.1093/scan/nsy018.
Saunders, B., Riesel, A., Klawohn, J., Inzlicht, M., 2018. Interpersonal touch enhances cognitive control: a neurophysiological investigation. J. Exp. Psychol. Gen. 147 (7), 1066–1077. https://doi.org/10.1037/xge0000412.
Scheele, D., Kendrick, K.M., Khouri, C., Kretzer, E., Schläpfer, T.E., Stoffel-Wagner, B., et al., 2014. An oxytocin-induced facilitation of neural and emotional responses to social touch correlates inversely with autism traits. Neuropsychopharmacology 39 (9), 2078–2085. https://doi.org/10.1038/npp.2014.78.
Schirmer, A., Gunter, T.C., 2017. The right touch: stroking of CT-innervated skin promotes vocal emotion processing. Cogn. Affect. Behav. Neurosci. 17 (6), 1129–1140. https://doi.org/10.3758/s13415-017-0537-5.
Schirmer, A., Teh, K.S., Wang, S., Vijayakumar, R., Ching, A., Nithianantham, D., et al., 2011. Squeeze me, but don't tease me: human and mechanical touch enhance visual attention and emotion discrimination. Soc. Neurosci. 6 (3), 219–230. https://doi.org/10.1080/17470919.2010.507958.
Seger, C.R., Smith, E.R., Percy, E.J., Conrey, F.R., 2014. Reach out and reduce prejudice: the impact of interpersonal touch on intergroup liking. Basic Appl. Soc. Psych. 36 (1), 51–58. https://doi.org/10.1080/01973533.2013.856786.
Sehlstedt, I., Ignell, H., Backlund Wasling, H., Ackerley, R., Olausson, H., Croy, I., 2016. Gentle touch perception across the lifespan. Psychol. Aging 31 (2), 176–184. https://doi.org/10.1037/pag0000074.
Serino, A., Giovagnoli, G., Làdavas, E., 2009. I feel what you feel if you are similar to me. PLoS One 4 (3), e4930. https://doi.org/10.1371/journal.pone.0004930.
Shamloo, S.E., Carnaghi, A., Fantoni, C., 2018. Investigating the relationship between intergroup physical contact and attitudes towards foreigners: the mediating role of quality of intergroup contact. PeerJ 6, e5680. https://doi.org/10.7717/peerj.5680.
Simão, C., Seibt, B., 2015. Friendly touch increases gratitude by inducing communal feelings. Front. Psychol. 6, 815. https://doi.org/10.3389/fpsyg.2015.00815.
Sorokowska, A., Saluja, S., Sorokowski, P., Frąckowiak, T., Karwowski, M., Aavik, T., et al., 2021. Affective interpersonal touch in close relationships: a cross-cultural perspective. Pers. Soc. Psychol. Bull., 146167220988373 https://doi.org/10.1177/0146167220988373.
Spapé, M., Harjunen, V., Ahmed, I., Jacucci, G., Ravaja, N., 2019. The semiotics of the message and the messenger: how nonverbal communication affects fairness

perception. Cogn. Affect. Behav. Neurosci. 19 (5), 1259–1272. https://doi.org/10.3758/s13415-019-00738-8.
Strauss, T., Kämpe, R., Hamilton, J.P., Olausson, H., Rottstädt, F., Raue, C., Croy, I., 2019. Deactivation of default mode network during touch. Sci. Rep. 9 (1), 1293. https://doi.org/10.1038/s41598-018-37597-1.
Sussman, N.M., Rosenfeld, H.M., 1978. Touch, justification, and sex: influences on the aversiveness of spatial violations. J. Soc. Psychol. 106 (2), 215–225. https://doi.org/10.1080/00224545.1978.9924173.
Suvilehto, J.T., Glerean, E., Dunbar, R.I., Hari, R., Nummenmaa, L., 2015. Topography of social touching depends on emotional bonds between humans. Proc. Natl. Acad. Sci. U. S. A. 112 (45), 13811–13816. https://doi.org/10.1073/pnas.1519231112.
Suvilehto, J.T., Nummenmaa, L., Harada, T., Dunbar, R.I.M., Hari, R., Turner, R., et al., 2019. Cross-cultural similarity in relationship-specific social touching. Proc. Biol. Sci. 286 (1901), 20190467 https://doi.org/10.1098/rspb.2019.0467.
Suvilehto, J.T., Renvall, V., Nummenmaa, L., 2020. Relationship-specific encoding of social touch in somatosensory and insular cortices. Neuroscience. https://doi.org/10.1016/j.neuroscience.2020.09.015.
Taneja, P., Olausson, H., Trulsson, M., Svensson, P., Baad-Hansen, L., 2021. Defining pleasant touch stimuli: a systematic review and meta-analysis. Psychol. Res. 85 (1), 20–35. https://doi.org/10.1007/s00426-019-01253-8.
Thompson, E.H., Hampton, J.A., 2011. The effect of relationship status on communicating emotions through touch. Cogn. Emot. 25 (2), 295–306. https://doi.org/10.1080/02699931.2010.492957.
Triscoli, C., Ackerley, R., Sailer, U., 2014. Touch satiety: differential effects of stroking velocity on liking and wanting touch over repetitions. PLoS One 9 (11), e113425. https://doi.org/10.1371/journal.pone.0113425.
Triscoli, C., Croy, I., Olausson, H., Sailer, U., 2017a. Touch between romantic partners: being stroked is more pleasant than stroking and decelerates heart rate. Physiol. Behav. 177, 169–175. https://doi.org/10.1016/j.physbeh.2017.05.006.
Triscoli, C., Croy, I., Steudte-Schmiedgen, S., Olausson, H., Sailer, U., 2017b. Heart rate variability is enhanced by long-lasting pleasant touch at CT-optimized velocity. Biol. Psychol. 128, 71–81. https://doi.org/10.1016/j.biopsycho.2017.07.007.
Trotter, P.D., McGlone, F., Reniers, R., Deakin, J.F.W., 2018. Construction and validation of the touch experiences and attitudes questionnaire (TEAQ): a self-report measure to determine attitudes toward and experiences of positive touch. J. Nonverbal Behav. 42 (4), 379–416. https://doi.org/10.1007/s10919-018-0281-8.
von Mohr, M., Kirsch, L.P., Fotopoulou, A., 2017. The soothing function of touch: affective touch reduces feelings of social exclusion. Sci. Rep. 7 (1), 13516 https://doi.org/10.1038/s41598-017-13355-7.
von Mohr, M., Crowley, M.J., Walthall, J., Mayes, L.C., Pelphrey, K.A., Rutherford, H.J. V., 2018a. EEG captures affective touch: CT-optimal touch and neural oscillations. Cogn. Affect. Behav. Neurosci. 18 (1), 155–166. https://doi.org/10.3758/s13415-017-0560-6.
von Mohr, M., Krahé, C., Beck, B., Fotopoulou, A., 2018b. The social buffering of pain by affective touch: a laser-evoked potential study in romantic couples. Soc. Cogn. Affect. Neurosci. 13 (11), 1121–1130. https://doi.org/10.1093/scan/nsy085.
Vrana, S.R., Rollock, D., 1998. Physiological response to a minimal social encounter: effects of gender, ethnicity, and social context. Psychophysiology 35 (4), 462–469.
Weller, A., Feldman, R., 2003. Emotion regulation and touch in infants: the role of cholecystokinin and opioids. Peptides 24 (5), 779–788. https://doi.org/10.1016/s0196-9781(03)00118-9.
Williams, G.P., Kleinke, C.L., 1993. Effects of mutual gaze and touch on attraction, mood, and cardiovascular reactivity. J. Res. Pers. 27 (2), 170–183. https://doi.org/10.1006/jrpe.1993.1012.
Willis, F.N.J., Briggs, L.F., 1992. Relationship and touch in public settings. J. Nonverbal Behav. 16, 55–63.
Willis, F.N., Rinck, C.M., 1983. A personal log method for investigating interpersonal touch. J. Psychol. 113 (1), 119–122. https://doi.org/10.1080/00223980.1983.9923565.
Willis, F.N., Rinck, C.M., Dean, L.M., 1978. Interpersonal touch among adults in cafeteria lines. Percept. Mot. Skills 47 (3 Pt 2), 1147–1152. https://doi.org/10.2466/pms.1978.47.3f.1147.