Journal of Affective Disorders 380 (2025) 375–383

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research paper

In search for affect in painful touch

Gianluca Cruciani [a], Pietro Zingaretti [b], Sergio De Filippis [b], Ludovica Zanini [c,*], Marco Iosa [d], Vittorio Lingiardi [c], Grazia Fernanda Spitoni [c,e]

[a] Department of Systems Medicine, University of Rome Tor Vergata, Via Montpellier 1, Rome, Italy
[b] Villa von Siebenthal Neuropsychiatric Hospital and Clinic, Via della Madonnina 1, Genzano di Roma, Rome, Italy
[c] Department of Dynamic and Clinical Psychology, and Health Studies, Sapienza University of Rome, Via degli Apuli, 1, Rome, Italy
[d] Department of Psychology, Sapienza University of Rome, Via dei Marsi, 78, Rome, Italy
[e] Cognitive and Motor Rehabilitation and Neuroimaging Unit, IRCCS Fondazione Santa Lucia, Via Ardeatina 306-354, Rome, Italy

ARTICLE INFO

Keywords:
Borderline Personality Disorder
Affective Touch
Self-harm
Nociception
Pain
C-tactile
Pleasant touch

ABSTRACT

Borderline Personality Disorder (BPD) is often linked to self-injurious behaviors, with many patients experiencing decreased pain sensitivity or analgesia during these episodes. In this work, we have shifted the theoretical standpoint from observing pain to observing tactile pleasure in BPD. Anchoring three linked experiments within the theoretical framework of the Affective Touch and the Social Touch Hypothesis, we studied a group of 28 BPD patients and 28 matched healthy controls. In Experiment 1, subjective pleasantness of CT-optimal tactile stimulations using various textured objects was tested. Results indicated that BPD patients rated rough and painful objects as more pleasant than controls. Experiment 2 examined self-administered touch, revealing that BPD patients preferred rough objects and used significantly greater force (triple) to achieve a pleasant sensation compared to controls, although both groups applied similar CT-optimal velocities. In experiment 3, we analyzed group performances when participants were asked to stimulate others' forearms in a pleasant manner as perceived by the receiver; no group differences in applied force or velocity were found. Overall, our findings suggest that in BPD patients, the perception of tactile pleasure involves the use of painful objects and the application of intense pressure on the skin; however, these features are not used when the patient needs to pleasantly stimulate others.

1. Introduction

Borderline Personality Disorder (BPD) is a complex and debilitating mental health condition characterized by pervasive patterns of instability related to intense emotional dysregulation, unstable interpersonal relationships, self-identity disturbances, chronic feelings of emptiness, intense fear of abandonment and specific behavioral expressions such as impulsivity and self-harming behavior (Bohus et al., 2021; Leichsenring et al., 2023). The latter symptom suggests a multifaceted and distressing expression of the emotional storm endured by individuals with the disorder. Those with BPD may turn to self-harm as a desperate effort to manage intense emotional distress, anxiety, or rage. Several authors have proposed that these conducts could serve as a way to externalize and regulate the emotional turmoil they frequently encounter (Colle et al., 2020; Reichl and Kaess, 2021). Marsha Linehan, one of the leading experts on BPD, asserts that individuals with BPD are not engaging in manipulation when they self-harm; rather, they are experiencing distress. Moreover, she suggests that self-harm is often an attempt to alleviate their suffering and find comfort (Linehan, 1993). Thus, it appears that individuals with BPD find relief and reassurance by self-inducing physical pain. This suggests that the inability to address psychological pain is transferred to a more manageable and easily manipulable object, namely the physical body. The naïve reasoning may lead one to wonder how psychological discomfort can be regulated by physical pain. In other words, how can adding physical pain to a state of emotional distress alleviate the latter?

Several authors have examined this phenomenon and the majority have questioned whether BPD patients have altered pain thresholds. For example, in a pioneering study, Schmahl et al. (2004) discovered that pain thresholds, measured through subjective ratings in response to laser-evoked pain, were notably elevated in individuals with BPD compared to healthy controls. Essentially, the study revealed that BPD patients require a greater intensity of heat than controls to experience pain. Subsequent research consistently supported these findings,

* Corresponding author.
E-mail address: ludovica.zanini@uniroma1.it (L. Zanini).

https://doi.org/10.1016/j.jad.2025.03.098
Received 28 August 2024; Received in revised form 21 January 2025; Accepted 18 March 2025
Available online 25 March 2025

demonstrating elevated pain thresholds in BPD patients (Ludäscher et al., 2007; Schmahl et al., 2004; Schmahl and Baumgärtner, 2015). More recently, Cruciani et al. (2023) further investigated and expanded upon this evidence by exploring whether reduced sensitivity extended to other somatosensory submodalities. The study revealed that individuals with BPD exhibited abnormal thresholds in warm detection, caloric warm pain, mechanical pain perception, and altered tactile sensitivity compared to matched healthy participants, suggesting an impairment not only in nociception but also in basic tactile sensitivity.

It seems reasonable to inquire whether these patients are capable of perceiving and appraising pleasant tactile stimuli. Stated differently, if the pain threshold is higher and tactile sensitivity significantly altered, could BPD patients also show an alteration in the range in which tactile stimuli are experienced as pleasant? Our study seeks to explore whether the self-harming behaviors observed in BPD patients might be influenced not only by the quest for emotional regulation but also by alterations in the preference of pleasant tactile stimuli. The theoretical framework guiding this study is the Affective Touch and the Social Touch Hypothesis (Olausson et al., 2010).

This framework originates from the identification of a group of unmyelinated cutaneous mechanosensory afferents that seem well-suited for detecting subtle pressure and movement on the skin (Nordin, 1990; Vallbo and Wessberg, 1993; Zotterman, 1939) and are referred to as C-tactile afferents (CTs). CTs respond specifically to gentle, slow, and stroking touch delivered at an intermediate frequency of 1–10 cm/s (Ackerley et al., 2014; Löken et al., 2009) and with low indentation force (Essick et al., 2010; Taneja et al., 2021). These fibers are involved in conveying pleasant tactile sensations and are believed to play a role in social bonding and emotional well-being. CT-fibers are hypothesized to mediate Affective Touch, which is associated with feelings of pleasure and comfort, and they are thought to contribute to the regulation of emotions and social interactions (McGlone et al., 2014; Olausson et al., 2010; Vallbo et al., 2009; for a recent review, see Fotopoulou et al., 2022). Vallbo et al. (2009) suggested that the crucial role of the CT system is likely to convey the pleasant aspects of light touch and that touch itself, from the very first moment of skin contact, is the driving force that generates positive tactile experiences (for an updated and comprehensive review on C-tactile afferents & Affective touch, see Schirmer et al., 2023). Moreover, it has been suggested that CT fibers may exert influence on pain modulation, potentially either heightening or dampening pain perception (Larsson and Nagi, 2022) and recent findings highlighted the connection between the CT-afferent system and pain. Optimal CT-stimulation has been shown to effectively alleviate acute pain, as demonstrated in several studies (for an updated and comprehensive review on CT-stimulation and pain, see Meijer et al., 2022). Finally, alteration of CT-fibers processing has been recognized in several psychopathological conditions such as anorexia nervosa (Cazzato et al., 2021; Crucianelli et al., 2016, 2021; Davidovic et al., 2018) and bulimia nervosa (Wierenga et al., 2020), as well as in individuals with insecure attachment patterns (Krahé et al., 2018) and disorganized attachment (Spitoni et al., 2020). This suggests that aberrant processing of social and interpersonal cues may influence the perception of pleasant touch.

The literature on BPD patients is notably limited and presents conflicting results. For example, Löffler et al. (2022) found that, compared to healthy controls, BPD patients perceived pleasant tactile stimulations as less pleasant and less intense. In contrast, a recent study (Cruciani et al., 2023) showed that BPD patients do not exhibit alterations in the perception and appraisal of affective touch. This inconsistency in the results prompted us to delve deeper into the study of BPD patients. Specifically, we designed a series of experiments to systematically investigate the physical characteristics of tactile stimulations that these patients perceive as pleasant. The rationale behind all three experiments is that, similar to self-harming behaviors, tactile stimulations typically considered uncomfortable might be perceived as pleasant by BPD patients, but not by healthy controls.

In the present study we compared BPD patients and healthy controls, and developed three concatenated experiments aiming to 1) examine group differences regarding the subjective pleasantness experienced in response to tactile stimulations delivered with objects typically perceived as uncomfortable or unpleasant; 2) analyze and measure the physical characteristics of self-stimulation (frequency and force) when asked to self-administer pleasant touch on the surface of their forearm; 3) analyze group performance when asked to stimulate others' forearm in a way that may be perceived as pleasant by the receiver.

2. Experiment 1. Object physical features and affective tactile perception: comparison between patients and healthy controls

2.1. Materials and methods

2.1.1. Participants

A selection of patients who had already participated in a previous study were included (see Cruciani et al., 2023). All the patients from the previous study were contacted again and asked to participate in this second study. Out of the original group, 28 consented and were included. All patients were on stable medication for 2 weeks prior to the experiment: the vast majority (96.43 %) of patients were on antipsychotics; additionally, 85.71 % of them were also treated with benzodiazepines, 32.14 % with hypnotic sedatives, and 82.14 % with mood stabilizers. All participants committed self-harming behaviors in the past quarter prior to the admission to the clinic, although quantitative data on self-harm were not collected in the present study. The group of patients was matched for demographic characteristics with 28 healthy controls. The demographic characteristics of the entire sample, the inclusion/exclusion criteria as well as a group comparison on severity of psychopathology are described in the Supplementary section (Supplementary 1, 2 and 3, respectively).

The present research was approved by the ethics committee of the Department of Dynamic and Clinical Psychology, and Health Studies, Sapienza University of Rome (Protocol number: 0001857) and conforms to the World Medical Association Declaration of Helsinki of 1975, as revised in 2008. All participants provided written informed consent prior to the experiment and were free to withdraw from the study at any time.

2.1.2. Procedure

Each participant underwent individual testing in a quiet room, and the experimental session lasted approximately 30 min. Following informed consent, only control participants were interviewed using the SCID-5-PD to exclude possible individuals with significant BPD traits (the patients had already been tested with a very extensive battery of tests when admitted to the clinic).

Participants were seated at a table with their dominant forearm resting palm-down. To prevent participants from seeing the stimuli, there was a specially designed panel (approximately 1 m by 1 m, 3 cm deep) with an arm opening at the base (15 × 20 cm) between the participants and the experimenter. They were instructed to remain still with their eyes closed throughout the procedure and to focus on the tactile sensation. Manual tactile stimulation of the participants' dorsal forearm was administered by the same experimenter, who was trained to stroke in a proximo-distal direction with consistent pressure and velocity using specific objects.

2.1.3. Stimuli

Stroking was delivered using 5 objects with differing textures (see Fig. 1), selected on the basis of a previous psychophysical pilot study. The pilot study revealed that while the makeup brush and wool evoked pleasant tactile sensations, the rotary wheel and sandpaper elicited unpleasant sensations of roughness and stinging. The sponge was rated as neutral.

Fig. 1. The five objects with differing textures used in Experiment 1 and 2, depicted in order of pleasantness (left: most pleasant, right: most painful). The objects were selected through ratings obtained in a previous psychophysical pilot study.

2.1.4. Task

The protocol included a total of 25 pseudorandomized trials: each object was used in 5 trials, and no object was reused until all four remaining objects had been used. Fig. 1 displays the five objects selected based on the pilot study: two with a soft texture, one neutral, and two with rough and sharp textures. Stroking was performed at the CT-optimal velocity of 3 cm/s. To assist the experimenter during stimulation, a 15 cm length and 4 cm height grid was drawn along the long axis of the participants' forearm. To minimize CT habituation, four different areas were delineated by the grid (two lateral and two medial) and were alternately stimulated.

Following each stimulation, participants were asked to rate their subjective perception of pleasantness using a 100 mm visual analog scale (VAS), with "not pleasant at all" (depicted by a sad face) and "extremely pleasant" (depicted by a smiling face) as endpoints. Participants were unaware of the objects used during the stimulations, and all objects were revealed to participants only at the conclusion of the protocol.

2.2. Statistical analysis

All statistical analyses were performed using the software Jamovi v. 2.4.11. To assess group differences in subjective pleasantness ratings across objects, a Linear Mixed Model (LMM) was implemented using the GAMLj Jamovi module, with Group (BPD and Controls) and Object (cosmetic brush, woolen fabric, sponge, sandpaper, and Wartenberg Pinwheel) as independent variables and the subjective pleasantness ratings for each stimulation as dependent variable.

2.3. Results

The LMM, aiming to assess the effect of Group and Object on participants' subjective pleasantness ratings, showed a significant model fit (*Conditional* $R^2 = 0.454$; $p < .001$; *Marginal* $R^2 = 0.215$; $p < .001$; $ICC = 0.304$). Model parameter estimates are reported in Supplementary 4.

The LMM showed a significant effect of Object ($F_{(4,1336)} = 106.565$; $p < .001$) on pleasantness ratings. Post-hoc comparisons revealed that the cosmetic brush was perceived as significantly more pleasant than the woolen fabric ($p < .001$), the sponge ($p = .001$), the sandpaper ($p < .001$) and the Wartenberg pinwheel ($p < .001$), the woolen fabric was more pleasant than the sandpaper ($p < .001$) and the Wartenberg pinwheel ($p < .001$), the sponge was more pleasant than the sandpaper ($p < .001$) and the Wartenberg pinwheel ($p < .001$), and the sandpaper was more pleasant than the Wartenberg pinwheel ($p < .001$). The LMM also yielded a significant Group x Object interaction ($F_{(4,1336)} = 30.956$; $p < .001$) on pleasantness ratings. Simple effects revealed that BPD patients rated the stimulations delivered with the cosmetic brush, the woolen fabric and the sponge as less pleasant than controls, and stimulations delivered with the sandpaper and the Wartenberg pinwheel as more pleasant than controls (Fig. 3). No significant effect of Group on pleasantness ratings was observed ($F_{(1,54)} = 0.146$; $p = .704$).

These results indicate that stimulation administered with soft objects were generally rated as more pleasant compared to those delivered with rough tools, and that in contrast to the control group, who rated stimuli as expected, participants with BPD consistently rated stimulation with different objects as equally pleasant. Additionally, BPD rated softer objects, such as woolen fabric and sponge, as less pleasant, while rougher and sharp objects (e.g., sandpaper and pinwheel) were rated as more pleasant compared to healthy controls.

3. Experiment 2. Self-administered pleasant touch: object, applied velocity, and force

3.1. Materials and methods

The participants and stimuli were the same as in Experiment 1.

3.1.1. Task

Participants were shown the five objects (see Fig. 1) and asked to both visually examine and physically interact with them. They were instructed to choose an object and utilize it to administer tactile stimulations that they found pleasant. These stimulations were to be conducted within the pre-defined grid (in a proximodistal movement from elbow to wrist), and participants were instructed to cease stimulation as soon as they felt the subjective pleasantness diminishing.

Participants sat at a table with their non-dominant forearm resting palm-down. They were asked to place the forearm on a flat surface capable of measuring pressure intensity (digital horizontal weighing scale); this device was connected to a camera with high temporal and spatial resolution that was activated whenever a participant began stimulating their own forearm. This apparatus enabled the video analysis of kinematic parameters such as the velocity of the stimulation (in cm/s) and the intensity of the force exerted on the forearm (in grams) during tactile stimulations. The entire setup was custom-made for this experiment by a bioengineer who co-authored this paper (MI). Fig. 2 shows the experimental setup.

Information about selected object, number of self-stimulations, applied velocity, and applied force were collected. Specifically, applied velocity was computed as follows: the duration of each stimulation was first calculated from the moment the selected object touched the skin to the moment the object was detached from the skin (obtained by visual inspection of video kinematic analysis with a procedure

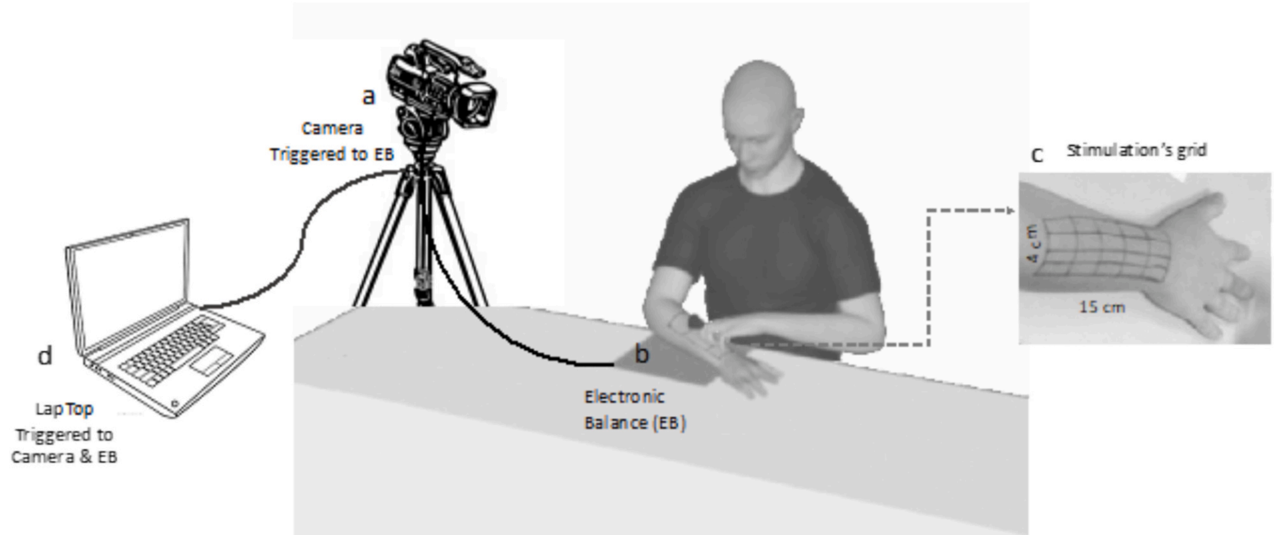

Fig. 2. The custom-made experimental set-up used during Experiment 2 to assess the force and velocity applied by participants during self-administered tactile stimulations.

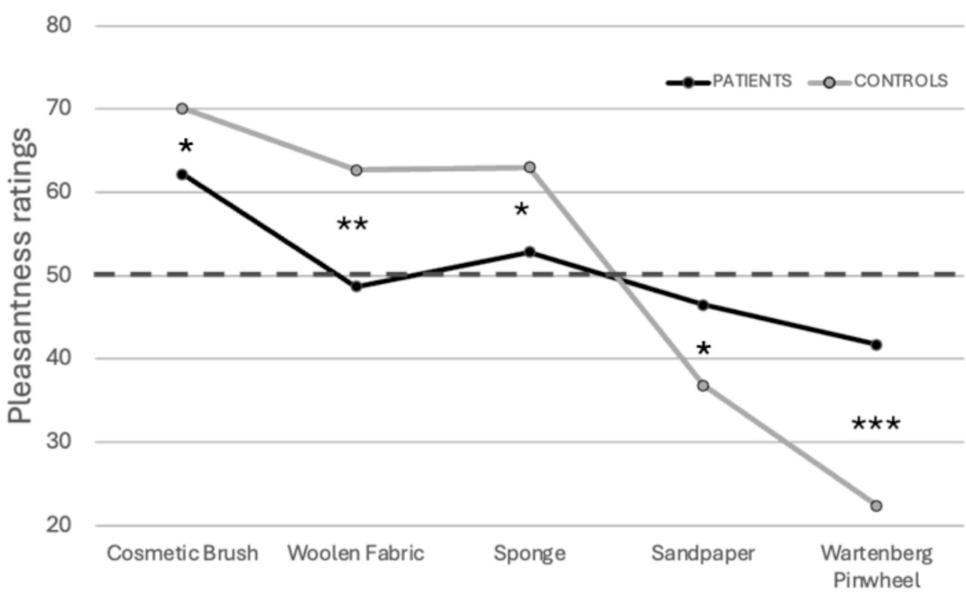

Fig. 3. Results of the simple effects analysis assessing the observed Group x Object interaction, revealing that, compared to controls, BPD patients tend to rate painful objects as more pleasant and pleasant objects as less pleasant. Pleasantness ratings depicted on the Y-axis ranged from 0 ("not pleasant at all") to 100 ("extremely pleasant").

analogous to the identification of stride events in video gait analysis (Åberg et al., 2021); the velocity of each stimulation was then calculated by dividing the length of the stimulated area (i.e., 15 cm) by the duration of the stimulation, expressed in cm/s; lastly, velocity was averaged across all the stimulations to obtain the mean employed velocity for each subject, expressed in cm/s. Regarding applied force, it was calculated as follows: force applied in the central section of the grid (7.5 cm from each side of the grid) was measured by a digital force platform for each stimulation; then, pressures were averaged across the stimulations to obtain the mean pressure for each subject; in order to control for variations due to the individual arm weight and movements, participants were asked to perform three catch trials at the end of the experiment, during which they performed the stimulations without actually touching their forearm, and force was measured at the moment the object was right above the central section of the grid: force collected during the three catch trials were then averaged and subtracted from the mean force collected during the actual stimulations to obtain the individual applied force net of arm weight and movement variations, and it was expressed in grams.

3.2. Statistical analysis

Descriptive analyses were conducted on the frequency of objects selected for the self-stroking task. A non-parametric Chi-square was also computed to test for group differences in object selection. A one-way ANOVA was performed to assess group differences in number of stimulations, applied velocity, and applied force during self-stroking. Eta Partial-square was calculated to quantify the effect size of comparisons.

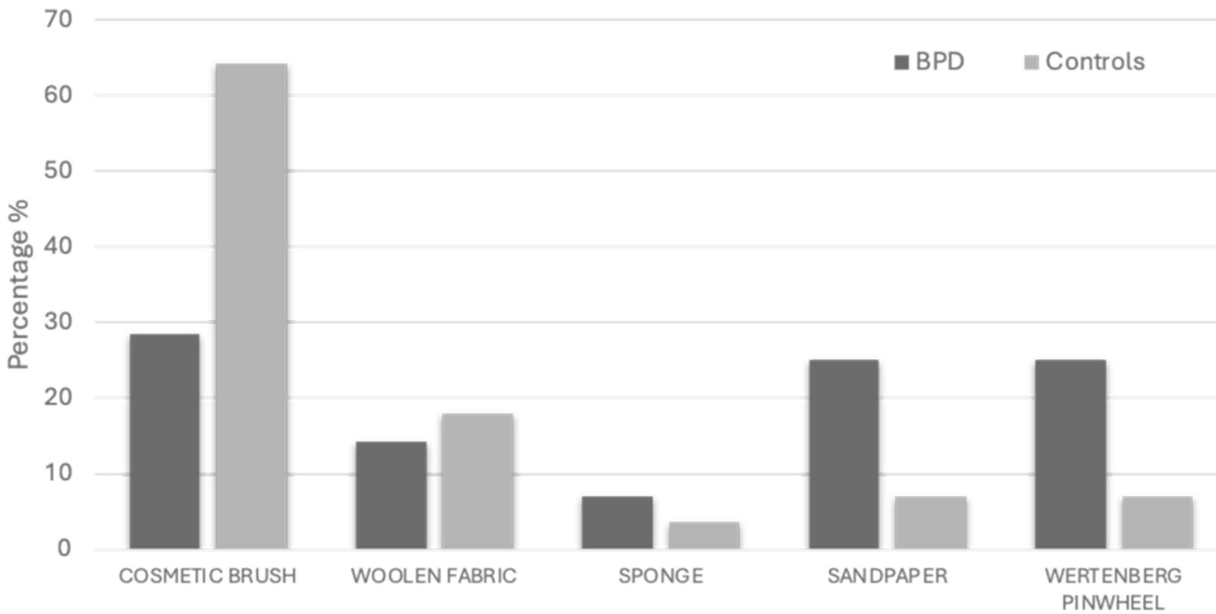

Fig. 4. Results regarding participants' object selection in Experiment 2 when asked to choose the object which, in their opinion, evokes pleasant sensations.

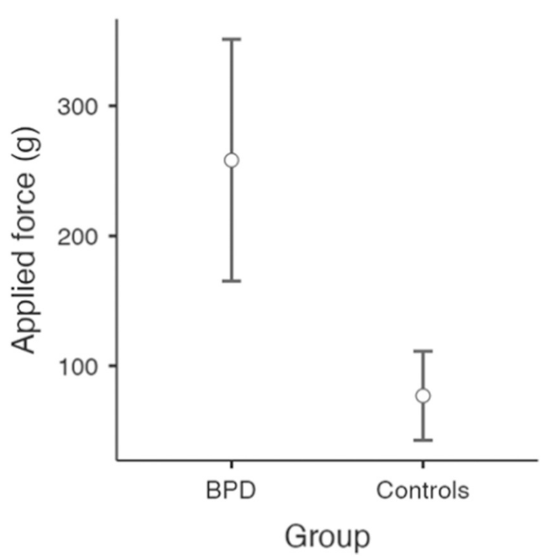

Fig. 5. Results regarding the force applied by the two groups (BPD patients and controls) in Experiment 2 during self-administered pleasant touch, illustrating that BPD patients employ 3 times the force to self-deliver pleasant touch.

3.3. Results

3.3.1. Object selection

The two groups significantly differed in the selection of the preferred object ($\chi^2 = 9.85$; $p = .043$). Fig. 4 shows the participants' choice in response to the question "choose the object that in your opinion is able to yield pleasant sensations".

It is interesting to note that the most significant differences are observed in the selection of extreme stimuli. Approximately 64 % of the control group chose the cosmetic brush, compared to only 28.5 % of the patients. Conversely, 50 % of the patients found the sandpaper (25 %) and the Wartenberg Pinwheel (25 %) pleasant, while – as expected - only 7 % of the healthy participants did.

3.3.2. Applied velocity

The two groups did not differ in terms of number of stimulations (BPD mean 15.07 ± 16.66; Controls mean 21.81 ± 22.88; $F_{(1,47.4)} = 1.552$; $p = .219$; *Partial eta squared* = 0.032), suggesting that both BPD patients and controls required a similar number of stimulations before the fading of the subjective pleasant sensation. No group differences were observed in applied velocity (BPD mean 6.16 ± 5.92 cm/s; Controls mean 6.71 ± 4.91 cm/s; $F_{(1,52.2)} = 0.143$; $p = .707$; *Partial eta squared* = 0.003), highlighting that both groups applied comparable velocities, which mostly were within the optimal range for CT activation (i.e., between 1 and 10 cm/s).

3.3.3. Force

Analyses revealed significant differences between BPD patients and controls regarding applied force (BPD mean 258.19 ± 240.02 g; Controls mean 77.04 ± 88.56 g; $F_{(1,34.2)} = 14.038$; $p < .001$; *Partial eta squared* = 0.291), with patients requiring more than triple the force to achieve a subjective pleasant sensation (Fig. 5).

4. Experiment 3. Participant interaction: stimulating the experimenter's forearm pleasantly

4.1. Materials and methods

4.1.1. Participants

Out of 28 patients, 8 (6 women) agreed to participate in the third study, which took place two weeks after the first two. The group of patients was compared with a group of 14 healthy participants with similar demographic characteristics. The features of the 22 participants are described in Supplementary 5.

4.1.2. Task

All participants were asked to stimulate the experimenter's forearm in a way which they supposed to be pleasant for the receiver; five trials were performed and all stimulations had to be delivered using the cosmetic brush. The same apparatus used in Experiment 2 was employed, and the applied velocity and force of stimulation were recorded.

4.2. Statistical analysis

One-way ANOVAs on applied velocity and force of stimulation were run. To further verify the robustness of the results, non-parametric analyses were also performed. This approach seems to be suitable for small sample sizes.

4.3. Results

Analyses revealed no group differences in terms of applied velocity (BPD mean = 5.22 ± 2.01 cm/s; Controls mean = 5.33 ± 2.98 cm/s; $F_{(1,19.3)} = 0.011$; $p = .919$; *Partial eta squared* = 0.001) and applied force (BPD mean = 50.05 ± 31.84 g; Controls mean = 53.36 ± 52.37 g; $F_{(1,19.8)} = 0.034$; $p = .856$; *Partial eta squared* = −0.002), suggesting that both patients and controls engage in similar modalities to stroke the forearm of the experimenter. Results from non-parametric analyses yielded comparable results and are reported in Supplementary 6.

5. Discussion

The aim of this study was to evaluate whether BPD patients show alterations in the perception of tactile pleasantness and, more importantly, whether tactile stimuli that typically scratch or injure are perceived similarly by both patients and controls. The study falls within the theoretical framework of the Affective Touch and the Social Touch Hypothesis (Olausson et al., 2010), and it is grounded on the clinical observation that BPD patients are often linked to self-injurious behaviors, with many patients experiencing decreased pain sensitivity or analgesia during these episodes. In this work, we have shifted the theoretical standpoint from observing pain to observing pleasure. Unlike existing studies that focused on the regulatory function of pain, our research takes an exploratory approach, proposing that painful self-stimulations may, among other functions, elicit the sensation of affective tactile pleasure. The literature indeed suggests that the firing frequency of CT fibers is positively correlated with subjective ratings of touch pleasantness and that – consistent with the affective touch hypothesis – CT fibers signal the rewarding value of affiliative touch (Morrison et al., 2010; Olausson et al., 2010).

5.1. Comparing object textures and affective tactile perception in BPD patients versus healthy controls

In the first study, participants rated the pleasantness of tactile stimuli delivered at a velocity considered optimal for the activation of CT fibers (i.e., 3 cm/s), using five different materials: two pleasant, one neutral, and two unpleasant. Comparing ratings between control participants and patients revealed that patients rated softer objects (cosmetic brush, woolen fabric and sponge) as less pleasant, while rougher and pointed objects (sandpaper and a pinwheel) were rated as more pleasant compared to healthy controls. Despite these differences, the statistical range of pleasantness ratings for all objects in the BPD group was narrower compared to controls suggesting that patients have a limited and less variable appreciation for affective tactile stimuli. In more straightforward terms, regardless of stimuli texture individuals with BPD experience minimal tactile pleasure.

This finding aligns with earlier observations indicating that individuals with BPD exhibit notably higher thresholds for tactile sensitivity (Cruciani et al., 2023). This suggests that, compared to controls, BPD patients need stronger mechanical stimulation to detect touch on their skin. Such a pattern is in line with a common characteristic of BPD patients, who often seek out intense sensory experiences to counteract feelings of emotional dis-control.

The skin, in this context, can be seen as a metaphorical barrier that both separates the individual from the external world, while also serving as a permeable membrane through which emotional experiences - positive and negative - are filtered and expressed.

The mechanisms behind this tactile/somatic barrier likely involve complex interactions between the limbic system, responsible for emotional processing, and the somatosensory cortices, which process touch and body-related sensations. Dysfunction in the frontolimbic network, namely the hyperactivations in patients with BPD in the bilateral amygdala and prefrontal cortex, and hypoactivations in bilateral inferior frontal gyri, may disrupt the typical integration of emotional and somatosensory information, leading to altered touch perception and potentially broader difficulties with tactile and body awareness (Lis et al., 2007; Niedtfeld et al., 2010; Niedtfeld and Schmahl, 2009; Schmahl and Bremner, 2006; Schulze et al., 2016; Schurz et al., 2024).

5.2. Exploring the features of self-administered touch: object, applied velocity, and force

In the second study, all participants were tasked with choosing an object and using it to provide themselves with pleasant tactile stimulations. The two groups displayed notable differences in their object selections. Particularly, significant variations were noted in extreme stimulus choices. For instance, around 64 % of the control group selected the cosmetic brush, as opposed to only 28.5 % of the patients. Conversely, 50 % of the patients selected either the sandpaper (25 %) or the pinwheel (25 %) as pleasurable objects, in contrast to the expected 14 % of healthy participants. Considering the specific modalities of self-administered touch, both groups showed similar patterns in terms of the number of stimulations needed before the pleasurable sensation diminished. Additionally, there were no group discrepancies observed in terms of applied velocity, indicating that both groups applied comparable speeds, largely falling within the optimal range for optimally activating CT fibers (i.e., between 1 and 10 cm/s). Regarding force, the analysis uncovered noteworthy differences between BPD patients and controls concerning the amount of force required to achieve a pleasurable sensation. Patients needed over triple the force compared to controls.

The results from this second experiment are particularly intriguing when considered in the context of the regulatory role of self-harm. Most studies have focused on the physical "pain" aspect of self-harm, neglecting the potential role of tactile pleasure. However, our data indicate that it is also possible to derive tactile pleasure from objects that cause pain. In line with the somatic barrier metaphor, it's not surprising that half of the patients, unlike their healthy counterparts, require more intense stimulation. Particularly noteworthy is the finding that the patients group needs to apply more than three times the pressure on their skin compared to healthy controls.

It is important to remember that the task's requirement was to stimulate the forearm to feel tactile pleasure; it almost seems that in this request there could be the recruitment of linked structures capable of processing affective tactile pleasure and physical pain concurrently.

This observation seems to be supported by a series of studies that have shown the analgesic effect of affective touch on physical pain (Krahé et al., 2016; Meijer et al., 2024a,b; von Mohr et al., 2018).

For example, in a work with several linked experiments on acute pain, Liljencrantz et al. (2017) showed that 1) CT-optimal touch significantly reduced the experience of acute pain compared to non-optimal CT stroking; 2) pain relief was most effective when CT-optimal touch preceded the acute pain stimulus directly. Likewise, research involving both adults and infants undergoing medical procedures has shown that CT-optimal touch can reduce pain experience by up to 50 % (Gursul et al., 2018). These results support the involvement of the CT-fiber system in pain modulation.

Nevertheless, a recent study highlighted a possible role of mechanoreceptive Aβ fiber in the processing of touch pleasantness (Case et al., 2023). The authors showed that when mechanoreceptive Aβ fiber function is experimentally diminished, the perceived intensity and pleasantness of gentle stroking or pressure are systematically decreased. Abnormal Aβ-driven tactile sensitivity among BPD patients has been previously described (Cruciani et al., 2023). Taken together, these results suggest that deficiencies in terms of tactile sensibility may contribute to an alteration of tactile pleasantness and pressure perception among BPD patients, requiring higher forces and more intense stimuli to perceive pleasant touch.

Various anatomo-physiological models, both bottom-up and top-down, have been proposed to clarify how the CT system and the pain system interact. Of course, this is not the place to delve into this topic, and reference is made to the comprehensive review by Meijer et al. (2022), where this is also addressed. The authors of this study put forth a new model that unfolds in two interconnected phases. One phase involves an inhibitory system in the spinal cord's dorsal horn, which effectively blocks pain signals from ascending pathways, resulting in a decrease in pain perception. In the other phase, the insula and ACC are down-regulated, further contributing to pain modulation (Meijer et al., 2022).

Lastly, the analgesic effect of AT has also been studied in relation to the activity of the autonomic nervous system (Smith, 2012) and the opioid and oxytocin systems (Ellingsen et al., 2016; Van Puyvelde et al., 2019).

Compared to our data, we could speculate that along with the emotional regulation function, the search for painful stimuli capable of inducing pleasure may serve BPD patients as a physiological component for reducing inner tension.

5.3. The subjective nature of tactile preferences

The third study is purely exploratory as the number of subjects is limited. In this study, we asked patients to stimulate the experimenter's forearm with the aim of allowing the experimenter to experience tactile pleasure.

In the previous experiment, the same patients exhibited atypical patterns of self-stimulation, often using more force than necessary. However, in the current experiment we found that, when stimulating the experimenter, the patients mirrored the typical speed and pressure of affective touch seen in control participants. This observation suggests that these patients may be aware that the perceptual characteristics of "others" differ from their own, and that the force they use for themselves may not be suitable for other individuals. It is possible that this ability to modulate touch for others, while exhibiting atypical self-stimulation patterns, reflects an underlying capacity for perspective-taking and social cognition. Research in the field of social neuroscience has demonstrated that observing others being touched can stimulate similar brain responses as directly experienced touch, enabling the discrimination touch pleasantness (Sadowski and Lomanowska, 2018). This suggests that the patients in the current study may have been able to simulate the experimenter's tactile experiences and adjust their stimulation accordingly. The potential implications of this finding are significant, as it suggests that – under experimental conditions – BDP patients may retain the ability to empathize with and attend to the tactile experiences of others. Nevertheless, considering the modest sample size of the present experiment and the absence of specific tests assessing participants' metacognitive abilities to take other's perspective, these observations remain speculative and should be interpreted with caution, and further studies are required to better address this issue.

5.4. Limitations

The most significant limitation of this study is the lack of direct analysis between self-harm and the style of affective stimulation. This was not carried out due to ethical considerations, as we were not permitted to delve into the quality and quantity of self-harming behaviors using psychometric measures that were considered too intrusive for some patients. The only information we gathered is qualitative and relates to the presence or absence of self-harming acts in the past quarter. In our opinion, the possibility of psychometrically measuring this data could have supported and strengthened the obtained data. A second limitation deals with the fact that in study 1 participants were only stimulated with one CT-optimal velocity (i.e., 3 cm/s), excluding the possibility of evaluating pleasantness ratings for velocities outside the optimal range of activation of CT fibers. This was not performed for several reasons: firstly, adding a third independent variable (i.e., velocity, in addition to group and objects) would have required a larger sample size to achieve robust results; secondly, although we chose a velocity that generally elicits pleasant sensations, it is known that there is relevant inter-individual variability in the perception of pleasant tactile stimulation (Croy et al., 2021), thus not ensuring a total control of the association between velocity and pleasantness. This association was in fact further explored in study 2 using a more ecological protocol in which participants were free to select a subjectively pleasant velocity. A third limitation concerns the absence of a clinical control group; future studies could take into consideration including another Cluster B personality disorder group (e.g., antisocial, narcissistic or histrionic personality disorder) to further differentiate the intra- and interpersonal specific characteristics of BPD patients associated with touch perception. An additional limitation derives from the possibility that patients' medication could have affected our findings. For instance, previous studies reported emotional blunting or numbing in response to the assumption of mood stabilizers (e.g., Goodwin et al., 2017; Peters et al., 2022) or antipsychotics (e.g., Kamitsis et al., 2022; Read and Williams, 2019). It is possible that medication could also have an effect on emotional and hedonic aspects of touch and future studies are warranted to better address this issue. Similarly, regarding our second experiment, future studies are warranted to further examine group differences in the force domain considering different objects singularly, by increasing the range of objects to be selected as well as including a larger sample size. Finally, our apparatus allowed a quantitative measure of velocity (kinematic analysis) and force (kinetic analysis), but not of pressure (force divided by the area of skin stimulated by the object).

6. Conclusion

Considering the comprehensive analysis presented, the current study delves into uncharted territory within the realm of touch perception in BPD patients. By investigating the affective and sensory responses of BPD individuals towards tactile stimuli, the research offers novel insights into how alterations in touch perception may be potentially linked to self-harming behaviors.

The study's embracement of the Affective Touch and the Social Touch Hypothesis opens avenues beyond the traditional focus on pain regulation towards understanding pleasure perception in these patients. By associating tactile experiences with emotional modulation, rather than pure pain responses, the research adds a nuanced perspective to the field. Notably, the findings reveal that individuals with BPD showcased distinct tactile preferences and responses compared to healthy controls, shedding light on the potential role of the search for pleasant touch in emotional regulation.

Furthermore, the use of self-administered touch tasks unveils intriguing disparities in object selection and force application between BPD patients and controls. The observed need for higher force in patients to achieve pleasurable tactile sensations underscores the intricate interplay between touch perception and emotional regulation in BPD. Such observations suggest a complex relationship between tactile processing, emotional states, and self-regulatory mechanisms in individuals with BPD.

The study's insight into the interplay between physical touch, emotional experience, and pain perception unveils a multifaceted perspective on the mechanisms underlying BPD symptomatology. The complex relationships between the mind and body highlighted in this study emphasize the intricate nature of touch perception and its impacts on emotional health in individuals with BPD. By exploring the links between tactile pleasure, self-harm tendencies, and emotional regulation, this research provides a distinct perspective for comprehending the intricacies of BPD symptom presentation.

CRediT authorship contribution statement

Gianluca Cruciani: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Pietro Zingaretti:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Sergio De Filippis:** Writing – review & editing, Supervision, Resources. **Ludovica Zanini:** Writing – original draft, Methodology, Data curation. **Marco Iosa:** Writing – review & editing, Software, Methodology. **Vittorio Lingiardi:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Grazia Fernanda Spitoni:** Writing – original draft, Supervision, Methodology, Conceptualization.

Funding

This work was supported by Sapienza University of Rome under the call for Progetti di Ricerca Medi 2019 (grant number: RM11916B88717775).

Declaration of competing interest

None.

Acknowledgments

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2025.03.098.

References

Åberg, A.C., Olsson, F., Åhman, H.B., Tarassova, O., Arndt, A., Giedraitis, V., Berglund, L., Halvorsen, K., 2021. Extraction of gait parameters from marker-free video recordings of Timed Up-and-Go tests: validity, inter-and intra-rater reliability. Gait Posture 90, 489–495.
Ackerley, R., Carlsson, I., Wester, H., Olausson, H., Backlund Wasling, H., 2014. Touch perceptions across skin sites: differences between sensitivity, direction discrimination and pleasantness. Front. Behav. Neurosci. 8, 54.
Bohus, M., Stoffers-Winterling, J., Sharp, C., Krause-Utz, A., Schmahl, C., Lieb, K., 2021. Borderline personality disorder. Lancet 398, 1528–1540.
Case, L.K., Madian, N., McCall, M.V., Bradson, M.L., Liljencrantz, J., Goldstein, B., Alasha, V.J., Zimmerman, M.S., 2023. Aβ-CT affective touch: touch pleasantness ratings for gentle stroking and deep pressure exhibit dependence on A-fibers. Eneuro 10.
Cazzato, V., Sacchetti, S., Shin, S., Makdani, A., Trotter, P.D., McGlone, F., 2021. Affective touch topography and body image. PLoS One 16, e0243680.
Colle, L., Hilviu, D., Rossi, R., Garbarini, F., Fossataro, C., 2020. Self-harming and sense of agency in patients with borderline personality disorder. Front. Psych. 11, 449.
Croy, I., Bierling, A., Sailer, U., Ackerley, R., 2021. Individual variability of pleasantness ratings to stroking touch over different velocities. Neuroscience 464, 33–43.
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.
Crucianelli, L., Demartini, B., Goeta, D., Nisticò, V., Saramandi, A., Bertelli, S., Todisco, P., Gambini, O., Fotopoulou, A., 2021. The anticipation and perception of affective touch in women with and recovered from anorexia nervosa. Neuroscience 464, 143–155.
Cruciani, G., Zingaretti, P., Lingiardi, V., De Filippis, S., Haggard, P., Spitoni, G.F., 2023. The perception of pain, discriminative touch and affective touch in patients suffering from Borderline Personality Disorder. J. Affect. Disord. 341, 185–193.
Davidovic, M., Karjalainen, L., Starck, G., Wentz, E., Björnsdotter, M., Olausson, H., 2018. Abnormal brain processing of gentle touch in anorexia nervosa. Psychiatry Res. Neuroimaging 281, 53–60.
Ellingsen, D.-M., Leknes, S., Løseth, G., Wessberg, J., Olausson, H., 2016. The neurobiology shaping affective touch: expectation, motivation, and meaning in the multisensory context. Front. Psychol. 6, 1986.
Essick, G.K., McGlone, F., Dancer, C., Fabricant, D., Ragin, Y., Phillips, N., Jones, T., Guest, S., 2010. Quantitative assessment of pleasant touch. Neurosci. Biobehav. Rev. 34, 192–203.
Fotopoulou, A., Von Mohr, M., Krahé, C., 2022. Affective regulation through touch: homeostatic and allostatic mechanisms. Curr. Opin. Behav. Sci. 43, 80–87.
Goodwin, G.M., Price, J., De Bodinat, C., Laredo, J., 2017. Emotional blunting with antidepressant treatments: a survey among depressed patients. J. Affect. Disord. 221, 31–35.
Gursul, D., Goksan, S., Hartley, C., Mellado, G.S., Moultrie, F., Hoskin, A., Adams, E., Hathway, G., Walker, S., McGlone, F., 2018. Stroking modulates noxious-evoked brain activity in human infants. Curr. Biol. 28, R1380–R1381.
Kamitsis, I., Harms, L., Bendall, S., 2022. The subjective effect of antipsychotic medication on trauma-related thoughts, emotions, and physical symptoms: a qualitative study with people who have experienced childhood trauma and psychosis. Psychol. Psychother. Theory Res. Pract. 95 (1), 256–276.
Krahé, C., Drabek, M.M., Paloyelis, Y., Fotopoulou, A., 2016. Affective touch and attachment style modulate pain: a laser-evoked potentials study. Philos. Trans. R. Soc. B 371, 20160009. https://doi.org/10.1098/rstb.2016.0009.
Krahé, C., von Mohr, M., Gentsch, A., Guy, L., Vari, C., Nolte, T., Fotopoulou, A., 2018. Sensitivity to CT-optimal, affective touch depends on adult attachment style. Sci. Rep. 8, 14544.
Larsson, M., Nagi, S.S., 2022. Role of C-tactile fibers in pain modulation: animal and human perspectives. Curr. Opin. Behav. Sci. 43, 138–144.
Leichsenring, F., Heim, N., Leweke, F., Spitzer, C., Steinert, C., Kernberg, O.F., 2023. Borderline personality disorder: a review. JAMA 329, 670–679.
Liljencrantz, J., Strigo, I., Ellingsen, D.M., Krämer, H.H., Lundblad, L.C., Nagi, S.S., Leknes, S., Olausson, H., 2017. Slow brushing reduces heat pain in humans. Eur. J. Pain 21, 1173–1185. https://doi.org/10.1002/ejp.1018.
Linehan, M., 1993. Cognitive-Behavioral Treatment of Borderline Personality Disorder. Guilford Press.
Lis, E., Greenfield, B., Henry, M., Guilé, J.M., Dougherty, G., 2007. Neuroimaging and genetics of borderline personality disorder: a review. J. Psychiatry Neurosci. 32, 162.
Löffler, A., Kleindienst, N., Neukel, C., Bekrater-Bodmann, R., Flor, H., 2022. Pleasant touch perception in borderline personality disorder and its relationship with disturbed body representation. Bord. Personal. Disord. Emot. Dysregul. 9, 3. https://doi.org/10.1186/s40479-021-00176-4.
Löken, L.S., Wessberg, J., McGlone, F., Olausson, H., 2009. Coding of pleasant touch by unmyelinated afferents in humans. Nat. Neurosci. 12, 547–548.
Ludäscher, P., Bohus, M., Lieb, K., Philipsen, A., Jochims, A., Schmahl, C., 2007. Elevated pain thresholds correlate with dissociation and aversive arousal in patients with borderline personality disorder. Psychiatry Res. 149, 291–296.
McGlone, F., Wessberg, J., Olausson, H., 2014. Discriminative and affective touch: sensing and feeling. Neuron 82, 737–755.
Meijer, L.L., Ruis, C., Van Der Smagt, M.J., Scherder, E.J.A., Dijkerman, H.C., 2022. Neural basis of affective touch and pain: a novel model suggests possible targets for pain amelioration. J. Neuropsychol. 16, 38–53. https://doi.org/10.1111/jnp.12250.
Meijer, L.L., Baars, W., Chris Dijkerman, H., Ruis, C., van der Smagt, M.J., 2024a. Spatial factors influencing the pain-ameliorating effect of CT-optimal touch: a comparative study for modulating temporal summation of second pain. Sci. Rep. 14, 2626.
Meijer, L.L., Ruis, C., Schielen, Z.A., Dijkerman, H.C., van der Smagt, M.J., 2024b. CT-optimal touch and chronic pain experience in Parkinson's disease; an intervention study. PLoS One 19, e0298345.
Morrison, I., Löken, L.S., Olausson, H., 2010. The skin as a social organ. Exp. Brain Res. 204, 305–314. https://doi.org/10.1007/s00221-009-2007-y.
Niedtfeld, I., Schmahl, C., 2009. Emotion regulation and pain in borderline personality disorder. Curr. Psychiatr. Rev. 5, 48–54.
Niedtfeld, I., Schulze, L., Kirsch, P., Herpertz, S.C., Bohus, M., Schmahl, C., 2010. Affect regulation and pain in borderline personality disorder: a possible link to the understanding of self-injury. Biol. Psychiatry 68, 383–391.
Nordin, M., 1990. Low-threshold mechanoreceptive and nociceptive units with unmyelinated (C) fibres in the human supraorbital nerve. J. Physiol. 426, 229–240. https://doi.org/10.1113/jphysiol.1990.sp018135.
Olausson, H., Wessberg, J., McGlone, F., Vallbo, Å., 2010. The neurophysiology of unmyelinated tactile afferents. Neurosci. Biobehav. Rev. 34, 185–191.
Peters, E.M., Balbuena, L., Lodhi, R.J., 2022. Emotional blunting with bupropion and serotonin reuptake inhibitors in three randomized controlled trials for acute major depressive disorder. J. Affect. Disord. 318, 29–32.
Read, J., Williams, J., 2019. Positive and negative effects of antipsychotic medication: an international online survey of 832 recipients. Curr. Drug Saf. 14 (3), 173–181.
Reichl, C., Kaess, M., 2021. Self-harm in the context of borderline personality disorder. Curr. Opin. Psychol. 37, 139–144.
Sadowski, A.S., Lomanowska, A.M., 2018. Virtual intimacy: propensity for physical contact between avatars in an online virtual environment. Comput. Hum. Behav. 78, 1–9.
Schirmer, A., Croy, I., Ackerley, R., 2023. What are C-tactile afferents and how do they relate to "affective touch"? Neurosci. Biobehav. Rev. 151, 105236.
Schmahl, C., Baumgärtner, U., 2015. Pain in borderline personality disorder. Pain Psychiatr. Disord. 30, 166–175.
Schmahl, C., Bremner, J.D., 2006. Neuroimaging in borderline personality disorder. J. Psychiatr. Res. 40, 419–427.
Schmahl, C., Greffrath, W., Baumgärtner, U., Schlereth, T., Magerl, W., Philipsen, A., Lieb, K., Bohus, M., Treede, R.-D., 2004. Differential nociceptive deficits in patients with borderline personality disorder and self-injurious behavior: laser-evoked potentials, spatial discrimination of noxious stimuli, and pain ratings. Pain 110, 470–479.
Schulze, L., Schmahl, C., Niedtfeld, I., 2016. Neural correlates of disturbed emotion processing in borderline personality disorder: a multimodal meta-analysis. Biol. Psychiatry 79, 97–106.
Schurz, M., Berenz, J.-P., Maerz, J., Perla, R., Buchheim, A., Labek, K., 2024. Brain activation for social cognition and emotion processing tasks in borderline personality disorder: a meta-analysis of neuroimaging studies. Brain Sci. 14, 395.
Smith, J.R., 2012. Comforting touch in the very preterm hospitalized infant: an integrative review. Adv. Neonatal Care 12, 349–365.

Spitoni, G.F., Zingaretti, P., Giovanardi, G., Antonucci, G., Galati, G., Lingiardi, V., Cruciani, G., Titone, G., Boccia, M., 2020. Disorganized attachment pattern affects the perception of affective touch. Sci. Rep. 10, 9658.

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, 20–35. https://doi.org/10.1007/s00426-019-01253-8.

Vallbo, A.B., Wessberg, J., 1993. Organization of motor output in slow finger movements in man. J. Physiol. 469, 673–691. https://doi.org/10.1113/jphysiol.1993.sp019837.

Vallbo, A.B., Olausson, H., Wessberg, J., 2009. Pleasant touch. In: Squire, L.R. (Ed.), Encyclopedia of Neuroscience. Academic Press, Oxford, pp. 741–748. https://doi.org/10.1016/B978-008045046-9.01916-1.

Van Puyvelde, M., Gorissen, A.-S., Pattyn, N., McGlone, F., 2019. Does touch matter? The impact of stroking versus non-stroking maternal touch on cardio-respiratory processes in mothers and infants. Physiol. Behav. 207, 55–63.

von Mohr, M., Krahé, C., Beck, B., Fotopoulou, A., 2018. The social buffering of pain by affective touch: a laser-evoked potential study in romantic couples. Soc. Cogn. Affect. Neurosci. 13, 1121–1130.

Wierenga, C.E., Bischoff-Grethe, A., Berner, L.A., Simmons, A.N., Bailer, U., Paulus, M.P., Kaye, W.H., 2020. Increased anticipatory brain response to pleasant touch in women remitted from bulimia nervosa. Translational psychiatry 10 (1), 236.

Zotterman, Y., 1939. Touch, pain and tickling: an electro-physiological investigation on cutaneous sensory nerves. J. Physiol. 95, 1.