An atypical social touch system in Anorexia Nervosa? Towards a novel non-invasive brain stimulation intervention

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Abstract

As outlined in Chapter 1, affective touch is a pleasant interoceptive stimulus facilitated by the activation of a specialised system of mechanosensitive cutaneous afferents C-tactile afferents (CTs), which respond when an individual receives gentle touch to the skin. The purpose of CTs is to encode the rewarding sensation of the touch that has been received. This type of touch is important for communication, bonding, and typical development. Numerous investigations have outlined that this process is associated with the activation of the Insula Cortex. In particular, the anterior and posterior regions respond when an individual receives affective touch to their hairy skin. In addition to this region, other brain regions specifically involved in social perception and social cognition, such as the medial Prefrontal Cortex (mPFC), have been implicated in affective touch processing. Furthermore, the role of the primary Somatosensory Cortex (S1), a key brain region for discriminatory touch processing, has been debated in terms of affective touch processing. More recently, investigations have shifted their focus from the general population to atypical responses to affective touch in clinical populations, specifically Anorexia Nervosa (AN). AN is an eating pathology characterised by restricted eating, body image distortions and impaired socio-cognitive abilities. It has been suggested that altered responses to affective touch may contribute to the aetiology and maintenance of this disorder.

Based on this evidence, study 1 (Chapter 3) aimed to examine whether women with high and low EDs risk differed in their responses to third-party vicarious social touch, delivered to various body regions at CT-optimal vs. non-CT optimal velocities. Forty-five women reporting high EDs risk symptoms vs. 40 women reporting low EDs risk symptoms viewed a sequence of video clips depicting one individual being touched by another, which was delivered to five body sites (cheek, back, ventral forearm, upper arm vs. palm). Participants were asked to rate how pleasant they perceived the touch to be when delivered at CT-optimal (5 cm/s) vs. CT non-optimal velocities (0 cm/s and 30 cm/s) for self-directed and other-directed touch. Self-report measures of body image concerns, interoceptive awareness and touch experiences and attitudes were also collected (outlined in Chapter 2). Surprisingly, touch pleasantness did not differ between both groups for both self-directed and other-directed touch. For high EDs risk females, eating disorder traits

and specific interoceptive awareness facets impacted pleasantness of touch for both the upper arm and back. Findings suggest that EDs traits and body awareness negatively affect ratings of social touch for specific body sites. However, results should be handled cautiously, given that women in this investigation did not have a clinical diagnosis of AN.

Therefore, given that women in study 1 did not have a formal AN diagnosis, study 2 (Chapter 4) investigated whether women with a current diagnosis of AN, recovered from AN (RAN) and Healthy Controls (HCs) responded differently to vicarious social touch also delivered at CT-optimal vs. non-CT optimal velocities. Thirty-five HCs, 27 AN and 29 RAN provided third-party pleasantness evaluations for two different tasks, one concerning self (self-directed touch) and one focused on touch to another person (other-directed touch). As in study 1, measures of body image concerns, interoceptive awareness and touch experiences and attitudes were administered through various questionnaires (outlined in Chapter 2). Results from this investigation revealed that both AN and RAN did not differ to HCs in their evaluations of touch directed to another person. However, both clinical populations rated self-directed CT-optimal touch as less pleasant compared to HCs. Thus, suggesting that both clinical groups display atypical responses to affective touch, when this touch is directed towards the self and not another person. In particular, that a learnt experience may contribute towards pleasantness responses to other-directed touch, as individuals with AN or RAN may be aware through experience that touch is pleasantly experienced by another, even if this is not the case for them.

Moreover, given that in study 2 individuals with AN demonstrated atypical responses to self-directed touch, study 3 (Chapter 5) examined whether this type of touch is mediated by the social relationship of that touch. Specifically, whether individuals with high and low levels of Body Image Disturbances (BIDs) differed in their responses to 'imagined' social touch. This was achieved through the use of an interactive mobile application, the 'Virtual Touch Toolkit' (See Chapter 2 for details). Sixty-nine high vs. low levels of BIDs completed heatmaps of front and back full body avatars, to indicate the intimate and social regions they find soothing/unpleasant to receive touch from a loved one vs. an acquaintance. In addition to this, various self-reports of interoceptive awareness and dysmorphic concerns were also collected. The results from this study revealed that both groups rated touch from a loved one as soothing, compared to touch from an acquaintance which was rated as unpleasant. For the high levels of BIDs group, greater emotional awareness predicted higher soothing ratings for touch provided from a loved one. Thus, findings support the idea that pleasantness responses to social touch are mediated by the relationships shared between the touch provider and receiver.

Lastly, study 4 (Chapter 6) aimed to understand the neural underpinnings related to atypical responses to social touch in AN. This study explored whether the primary somatosensory cortex (S1) and the ventromedial prefrontal cortex (mPFC) are involved in affective touch processing. In order to investigate this, 18 healthy control participants received offline continuous theta burst Transcranial Magnetic Stimulation (cTBS), a form of repetitive transcranial magnetic stimulation (rTMS) to the right vmPFC, S1 and Vertex (control). After this, participants provided ratings of self-directed vicarious touch and other-directed touch. In addition, self-report measures of interoception, body image concerns and touch experiences and attitudes were collected (Detailed in Chapter 2). Findings from this study revealed that vmPFC-cTBS reduced pleasantness ratings for other directed touch but not for self-directed touch. S1-cTBS increased pleasantness ratings for self-directed touch but had no effect on pleasantness ratings for other-directed touch. The reduction in pleasantness for other-directed touch and the increase in pleasantness for self-directed touch was not CT-specific. Overall, results from this study imply that both S1 and vmPFC have distinctive roles in social touch processing and the processing of CT-optimal touch occurs outside of these social brain regions. This study offers important consideration for future non-pharmacological intervention which could improve touch processing in individuals with AN regardless of CT-optimality (Chapter 6).

Taken together, findings from these investigations suggest that women with AN and recovered from AN display comparable intact evaluations when comparing touch for another person, similar to HCs. However, atypical responses to affective touch occur when asked to make judgements for touch to the self, with both clinical groups rating this touch as less pleasant than HCs (Chapter 4). These results do not extend to high EDs risk, who display typical and comparable responses to self and other-directed touch to HCs

(Chapter 3). Overall, responses to social touch have been found to be modulated by the relationship shared with the touch provider, with more familiar individuals being more positive and more distant being more unpleasant (Chapter 5). Furthermore, although there is some distinctive involvement of vmPFC and S1 in social touch processing, it is evident that the processing of CT-optimal touch occurs outside of these regions, such as the orbitofrontal cortex (OFC) and anterior cingulate cortex (ACC).

Overall, results from these investigations offer valuable insight into responses to vicarious social touch in women at risk of EDs, women with AN and recovered from AN (Chapters 3 and 4). Based on this, results offer the potential for future pilot studies to be developed, incorporating both TMS and mobile applications as an intervention for atypical responses to self-directed touch in individuals with AN (discussed in Chapter 7).

Declarations

I declare that this thesis is my own work and has not been previously submitted for an award.

Signed: **Date:** 11th February 2024

The study outlined in Chapter 4 has been published in:

Bellard, A., Trotter, P., McGlone, F., & Cazzato, V. (2022). Vicarious ratings of self vs. other-directed social touch in women with and recovered from Anorexia Nervosa. *Scientific Reports, 12*(1), 1-15.

The study outlined in Chapter 5 has been published in:

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The study outlined in Chapter 6 has been published in:

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Components of these studies detailed in Chapters 3, 4, 5, and 6 have been presented at the following conferences and workshops:

- Bellard, A., Sun, W., Denkow, L., Najm, A., Michael-Grigoriou, D., Trotter, P., McGlone, F., Fairhurst, M., & Cazzato, V., (2021, November 12). The virtual touch toolkit: Association with body image disturbances and responses to interpersonal touch, as measured by the 'hands on' application [Conference presentation]. BIRD 2021, Online, Australia., BIRD 2021, Online (Australia), Poster presentation. 2021
- Bellard, A., Trotter, P., McGlone, F., & Cazzato. V (2021, June 3-24). The impaired affective touch system in Anorexia Nervosa: A non-invasive brain stimulation technique (TMS) [Presentation]. Liverpool John Moores University, 3 Minute Thesis competition.
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- Bellard, A., Sun, W., Denkow, L., Najm, A., Michael-Grigoriou, D., Trotter, P., McGlone, F., Fairhurst, M., & Cazzato, V., (2022, May 4). The virtual touch toolkit: Association with body image disturbances and responses to interpersonal touch. [Poster session]. Body-Up Conference 2022.
- Bellard, A., Trotter, P., McGlone, F., & Cazzato. V (2022, May 3-11). The impaired affective touch system in Anorexia Nervosa: A non-invasive brain stimulation technique (TMS) [Presentation]. Liverpool John Moores University, 3 Minute Thesis competition.
- Bellard, A., Trotter, P., McGlone, F., & Cazzato. V (2022, June 24). Neural underpinnings of vicarious ratings of social touch in women at risk from eating disorders: A Transcranial Magnetic Stimulation (TMS) study. [Poster Presentation]. Liverpool Neuroscience Day 2022.

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Chapter 1
General Introduction

1.1 Background

"*Touch is ten times stronger than verbal or emotional contact. Touch is not only basic to our species, but the key to it."* (Montagu, 1971).

The main aim of this PhD project was to offer further understanding into the aetiology of AN, by investigating whether individuals with AN display atypical self and other-directed vicarious social touch responses and to understand the neural underpinnings potentially surrounding these evaluations, using both behavioural and neurophysiological measures such as Transcranial Magnetic Stimulation. This understanding can assist with the development of a future non-invasive brain stimulation intervention to target brain regions relating to atypical responses to social touch in AN.

A large amount of research has emphasised the importance of touch to human development, social bonding, and wellbeing (Brauer et al., 2016; Cascio et al., 2019; Morrison et al., 2010; von Mohr et al., 2017). As found previously with animal studies (Bessou et al., 1971; Douglas & Ritchie, 1957; Iggo & Kornhuber, 1977; Kumazawa & Perl, 1977; Pitcher et al., 2016; Zotterman, 1939), humans also possess a specialised system of mechanosensitive cutaneous afferents, called C-tactile afferents (CTs), hypothesised to be involved in the emotional encoding of the rewarding sensation associated with touch to the skin (Morrison, 2016). When an individual is gently stroked, this stimulates slow conducting, unmyelinated mechanosensory nerves, CTs, which innervate hairy, but not glabrous skin (the smooth, hairless part of the skin) (Ackerley et al., 2014; Löken et al., 2009; McGlone et al., 2014). From the receptors in the skin, unmyelinated afferents project to the laminae of the spinal cord, with C-type fibres projecting to lamina I & III in the dorsal horn (Sugiura, Lee, & Perl, 1984). From here CTs and C-nociceptor afferents (which respond to more painful and harmful stimuli such as pain through injury and extreme temperatures; Dubin & Patapoutian, 2010) project to the dorsal posterior insula cortex, which underpins the interoceptive system, which is a system which enables an individual to understand and feel what is happening inside the body (Craig, 2009; Lamm & Singer, 2010). Interoception is the understanding of the physiological condition of the body, which combines information from both internal sensations such as cardiac and respiratory signals, with external bodily sensations such as pleasure and pain (Armstrong, 2019). Electrophysiological studies utilising microneurography have found that CTs respond optimally to touch applied to hairy skin sites between 1 and 10 cm/s, in which the subjective pleasantness of touch varies depending on velocity (Vallbo & Hagbarth, 1968; Nordin, 1990; Vallbo et al., 1999; Löken et al., 2009). This system responds optimally when the hairy skin is lightly stroked at a velocity of 3 cm/s, which generates the greatest hedonic rating (Croy et al., 2016; McGlone et al., 2014). This type of touch, known as affective touch, generates a distinct pleasant, hedonic feeling through the activation of interoceptive pathways. Functional neuroimaging studies have revealed that the Insula Cortex, plays different roles in the processing of affective touch. Particularly, the dorsal posterior Insula is the recipient for CT-afferents, with a specific role involving the anticipation of the sensations of future affective touch (Björnsdotter & Olausson, 2011; Craig, 2002; Olausson et al., 2002; Marshall et al., 2019). The posterior Insula is thought to be sensitive to the velocity of the interoceptive cues and has found to be most responsive to a velocity of 3 cm/s (Morrison et al., 2008; Björnsdotter & Olausson, 2011), with the anterior region playing a key role in CT pleasantness sensitivity (Kirsch et al., 2020). The signal from the posterior Insula is re-represented in the mid and anterior Insula, which integrates interoceptive information with contextual information (Critchley et al., 2004; Craig, 2009; Evrard, 2019). The Insula Cortex is therefore the recipient of input from internal bodily states, contributing to interoceptive processing (Craig, 2002; Kirsch et al., 2020). Both forms of information are key in body awareness and the sense of self (Craig, 2002). Overall, prior research has suggested that affective touch is a sub-modality of interoception, processed by the Insula Cortex, which conveys affective and affiliative aspects of social touch (Krahé et al., 2018).

As well as the Insula Cortex, other regions involved in social cognition and social perception are also involved in the processing of actual affective touch (Gallagher & Firth, 2003; Koster-Hale & Saxe, 2013), such as the medial prefrontal cortex (mPFC) (Chen et al., 2020; Gordon et al, 2011, 2013; Voos et al., 2013), representing the social importance and significance of touch in a given situation (Gordon et al., 2013). In addition to social cognitive regions, several investigations have suggested there to be an association between touch pleasantness and activation of the primary somatosensory cortex (S1) (McCabe et al., 2008; Gazzola et al., 2012). Nevertheless, the involvement of this region has been under debate and more research investigating the role of social cognitive regions in affective touch processing is required.

In addition not only do individuals positively experience affective touch through actively receiving touch, this hedonic sensation associated with touch is also experienced from vicarious (observed) touch (Keysers et al., 2004; Morrison et al., 2011; Schaefer et al., 2012). This hedonic experience of observed touch occurs in the absence of CT activation. Nonetheless, regardless of the lack of CT activation, higher pleasantness response to observed touch has been previously found in relation to CT-optimal touch, and was also body part specific i.e., when vicarious touch was provided to body regions with higher CT innervation such as the back (Morrison et al., 2011; Walker et al., 2017). This finding can be explained by the embodied simulation theory, which suggests that vicarious touch involves the automatic and unconscious experience and sensation associated with observing another individual receiving touch. The observer experiences the feeling of the touch they are perceiving as though they themselves are actual experiencing this touch (Gallese & Ebisch, 2013; Gillmeister et al., 2017). In order to experience a shared experience of the touch being observed, the same neural networks involved in our own touch experiences system are also similarly involved when we observe another receiving touch, which occurs due to a visuo-tactile mirroring mechanism (Gallese, 2005; Gallese & Lakoff, 2005). As revealed in fMRI investigations, this shared experience of touch is associated with the activation of the both the primary and secondary somatosensory cortices, which are regions also involved in the direct experience of actual touch (Keysers et al., 2010). A repetitive transcranial magnetic situation (rTMS) study conducted by Bolognini et al. (2011) demonstrated that disruption to S1 impaired participants perception of touch being delivered to another individual’s hand. As well as the somatosensory cortices, other regions such as the insula cortex, superior temporal sulcus and orbital frontal cortex are also activated for both the observed and actual experience of touch (Blakemore et al., 2005; Ebisch et al., 2008; Keysers et al., 2004, 2010; Masson et al., 2018; Pihko et al., 2010; Schaefer et al., 2012; Chapter 1.2.6).

Importantly, given that no differences in responses have been reported in relation to actual and observed touch (Keysers et al., 2004; Morrison et al., 2011; Schaefer et al., 2012), using observed touch has fewer confounds. In particular, actual touch experiments do not resemble the affective, gentle touch an individual would receive in a real life, instead all touch is provided through a brush and/or by a stranger (unfamiliar researcher), which may lead to more negative responses towards touch. Using observed touch, allows for the research to control for factors such as the relationship i.e., who the individual is imagining the touch is being given from. As outlined previously, the type of touch, the body areas allowed to be touched and the affective response is largely impacted by the closeness of the touch giver and receiver (Gazzola et al., 2012; Jones & Yarbrough, 1985; Nummenmaa et al., 2016; Strauss et al., 2020; Suvilehto et al., 2015, 2019, 2021; Willis & Briggs, 1992). Using observed touch as opposed to real touch is particularly important when assessing responses to touch in clinical populations, such as Anorexia Nervosa. Using this form of assessment is an alternative way to examine social touch responses without having to provide real touch, which could be distressing to individuals with AN, particularly to weight sensitive body regions, as these populations experience greater intensity and hypersensitivity to real touch (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021). Furthermore, as outlined by Gillmeister et al. (2016) studies which focus on responses to vicarious touch in clinical populations are lacking and therefore require more attention.

1.1.2 Atypical affective touch responses in Anorexia Nervosa (AN)

Nonetheless, despite affective touch being perceived as most pleasant in typically developing populations (Keizer et al., 2022), the hedonic value of touch is perceived as unpleasant in individuals with eating disorders specifically Anorexia Nervosa (AN) (Crucianelli et al., 2016, 2021; Davidovic et al., 2018). AN is an eating pathology typically characterised by body image disturbances in the perception of their body (external processing), impaired interoception - awareness of bodily signals (internal processing), such as pain, hunger etc., resulting in restrictive eating, a significantly low body weight, low BMI maintenance, restriction of food intake, malnutrition, and fear of weight gain. Previous research has revealed that impairment in the affective touch system is the key to the maintenance of AN, specifically for body image disturbances such as in the visual, attitudinal, and physiological aspects of their body image (Strigo et al., 2013; Kaye et al., 2009; Nandrino et al., 2012). Due to impairments in perception, individuals with AN typically perceive their body as larger than their actual body size and demonstrate an overestimation of their body image (Farrell et al., 2005; Smeets et al., 1997; Skrzypek et al., 2001; Stice & Shaw, 2002), and experience negative attitudes towards their body such as body dissatisfaction (Cash & Deagle, 1997). Furthermore, individuals with AN experience a distorted physiological (internal function) sense of self i.e., they have impaired bodily awareness of internal processes of the body, referred to as interoceptive awareness, which is the core of internal self-representation (Craig, 2002; Kaye et al., 2009; Pollatos et al., 2008). One internal sensation individuals with AN are believed to atypically process is affective touch (Crucianelli et al., 2016; Davidovic et al., 2018). As implied by Ciaunica and Fotopoulou (2017) and Gentsch et al. (2016) affective touch may potentially be exclusively involved in bodily self-representation such as the physiological state of internal state of the body, the distinction between self and others, the mental representation of the body and the perception of the body in the external world (Ciaunica & Fotopoulou, 2017; Gentsch et al., 2016). Thus, atypical responses to affective touch may serve as a contributor towards body image disturbances in AN. Given that previous studies have found reduced pleasantness in individuals with AN (Crucianelli et al., 2016, 2021; Davidovic et al., 2018), and that observing touch activates touch experiences and corresponding brain regions such as the Insula Cortex and Somatosensory Cortex (Lee Masson et al., 2017, 2018), it is anticipated that when people with AN are asked to rate the perceived pleasantness of others receiving affective touch, they will use their own experiences to interpret the feelings generated in another, which could account for an impaired ToM in individuals with AN and disconnection with their body (Gál et al., 2011; Hamatani et al., 2016; Kolnes, 2012; Russell et al., 2009; Tchanturia et al., 2018; Zucker et al., 2007). Therefore, atypical affective touch responses may also be linked to social deficits (Bora & Kose, 2016; Tchanturia et al., 2018). Individuals with AN are more reserved and are suggested to have a small number of social relationships and struggle to maintain high quality relationships (Tchanturia et al., 2013; Tiller et al., 1997). This could be as a result of patients with AN demonstrating atypical response to pleasant sensations associated with social interactions, such as social anhedonia (Crucianelli et al., 2021; Tchanturia et al., 2013).

Not only is interoceptive awareness important for perception of the body but also exteroceptive processing (signals from outside of the body) (Blanke et al., 2015; Tsakiris, 2010), which goes hand in hand with one another (Ainley et al., 2012). Thus, AN symptomatology could arise consequent to the imbalance between interoception and exteroception. In support, a review by Badoud and Tsakiris (2017) revealed that basic interoceptive processes and awareness, may both contribute towards body image concerns and disturbances in AN. In particular, lower interoceptive accuracy is associated with greater body image concerns and misperception. Therefore, offering support for the link between an imbalance in interoceptive and exteroceptive processing and the maintenance of symptoms associated with AN.

Overall, body image disturbances in AN are suggested to occur consequent to a lack of sense of self, such as a poor identification of both the visual and physical aspects of self, in addition to the lack of understanding of the internal condition of the body, arising due to an impaired interoceptive awareness (Badoud & Tsakiris, 2017; Berner et al., 2018; Gaudio et al., 2014). Therefore, this PhD project aimed to contribute towards the understanding of the processing of affective touch in AN and whether this contributes towards the maintenance of this eating pathology. This was achieved through investigating, using behavioural methods, responses to vicarious affective touch applied to different body regions, at different velocities, in high EDs risk compared to low EDs risk. Furthermore, this was also assessed using both current and remitted AN and comparing their responses to healthy control participants.

Furthermore, the aetiology surrounding AN remains unknown and requires further investigation and as such already established interventions e.g., family-based therapy, cognitive behavioural therapy, group cognitive based therapy, medication, and hospitalisation, which aim at targeting AN symptomatology are largely unsuccessful (Costanzo et al., 2018). Due to the poor success rates for already established interventions, the UK National Institute for Health and Care Excellence have emphasised the need for novel treatment interventions for individuals with AN, as traditional interventions lack effectiveness, resulting in recurrent relapsing and fatality in severe circumstances

(Costanzo et al., 2018). More recently, brain stimulation procedures, such as Transcranial Magnetic Stimulation (TMS), which is a non-invasive brain stimulation technique involving applying a magnetic coil on an individual's scalp and inducing an electric current to specific brain regions, in order to depolarize axons and cortical networks (Habib et al., 2018), has been put forward as a potential treatment technique for the treatment of AN. This technique can also be used to enhance brain functioning by improving inter-neuronal connectivity (Duriez et al., 2020; Luan et al., 2014). This technique has become more popular as a treatment intervention and has been proposed as a potential treatment for AN, as this method can be used to stimulate (enhance) or inhibit (reduce) brain activity to a targeted region.

Based on this, the current PhD project involved the use of TMS to understand what the key brain regions involved in affective touch processing are. This project incorporated neurophysiological techniques such as neuro-navigated repetitive TMS to disrupt functioning both the mPFC and S1, in order to assess the importance of these regions in vicarious affective touch processing and the association with AN symptomatology. This study was key in understanding the aetiology surrounding AN, particularly some of the brain regions which may be impaired and contribute towards their atypical responses to social touch. In better understanding this, more successful treatment interventions can be developed resulting in higher treatment success rates. TMS could be used as a potential future novel non-invasive brain stimulation intervention targeting the regions identified as impaired in this PhD project, which could help reduce relapse rates and enhance patient engagement with treatment.

Moreover, the cost in the UK alone for AN treatment is approximately £18 billion due to patients requiring multiple treatment sessions due to recurring relapsing. Thus, due to this cost, there is a strong emphasis for more understanding surrounding this condition in order for more successful and economical interventions to be developed. Therefore, this PhD project is important in providing more understanding of the aetiology of this condition and to provide a basis for a more successful low-cost treatment intervention for AN to be developed. In doing so, this will help reduce the number of reported fatalities associated with this disorder. If shown to be successful, it will aid in reducing additional costs for relapsing patients, which other interventions have failed to accomplish due to this lack of understanding.

Based on the above, Chapter 1.2 of this thesis will provide a review of what is touch and will highlight the importance of and the different types of touch including interoceptive affective stimuli. This chapter will provide an overview and understanding of the biological basis of the CT-system and its association with affective touch and will focus on both the understanding of interoceptive and exteroceptive modalities of affective touch and how the two are connected. In addition, the comparison between actual and observed touch will be discussed. This chapter will also offer insight into the system and brain regions involved in the processing of actual and vicarious social touch. Furthermore, Chapter 1.3 will explain what anorexia nervosa is and the connections with interoception. This chapter will also outline previous research which has demonstrated that AN display atypical response to affective touch and the brain regions largely involved in these responses. Chapter 2 will provide an overview of the methods used to measure vicarious affective touch responses in individuals with AN. This chapter details all the methods used in each study such as self-report questionnaires, the exteroceptive measures and the affective touch tasks used. Also, this chapter provides an overview of the non-invasive brain stimulation (NIBS) in study 4. This is used to investigate the specific role of an area of the brain (Hallett, 2007; Horvath et al., 2011). In order to measure this specific role, this measure temporarily interferes with the neural functioning of a targeted cortical brain region (Horvath et al., 2011) by either exciting or inhibiting this region (Hallett, 2007).

Chapter 3 will illustrate a baseline study which demonstrates affective touch responses in individuals with high and low eating disorder risk through the observation of touch (study 1). Importantly, Study 2 investigated the observation of affective touch and the association with eating disorder traits, through the use of third-party vicarious ratings of affective touch videos and various self-report scales assessing AN symptomatology in individuals with current and remitted AN. This study contributed towards the aim of providing a proof-of-concept for atypical responses to affective touch in AN consequent to an atypical social cognitive ability to attribute pleasantness feelings at CT-optimal vs. non optimal velocities (Chapter 4). Chapter 5 will describe the third study which examined the use of a self-touch hands on app to determine the use of this tool in measuring both body image disturbances and touch impairments in individuals at risk of an EDs. Based on the findings from study 2, relating to atypical responses to self-directed touch in AN and RAN, this study examined whether responses to self-directed touch in individuals in AN is dependent upon the social context, specifically the relationship of the touch provider (Study 3). Chapter 6 detailed a fourth study, which assessed the neural underpinning of affective touch in relation to AN symptomatology. This study used repetitive TMS with a theta-burst protocol in order to establish the causal role of the medial Prefrontal Cortex and the primary Somatosensory Cortex in affective touch processing for self-directed and other-directed social touch and their links with body image disturbances (Study 4). Chapter 7 will provide conclusions based on findings from all investigations and will provide directions for future investigations and how this PhD can be developed further in the future such as through the development and pilot of a non-invasive brain stimulation intervention.

Chapter 1.2

Touch

1.2.1 What is Touch?

Touch is one of the first sensations that we experience, as the skin, one of our largest sense organs, is the first to develop during foetal development in the womb (Field, 2001; Montagu, 1971). The earliest sensation of touch occurs when a foetus experiences stimulation by the amniotic fluid. Once born, an infant's first experience of touch occurs through the tactile stimulation they receive from their mother or caregiver (Brzozowska et al., 2022; Lagercrantz & Changeux, 2009).

Touch is one of the most important sensations that we develop, as it is believed to play an important role in the distinction of self from another and also enables us to receive information from the external world (Field, 2001). Touch enables the formation of strong bonds and interpersonal relationships with others. As outlined by the 'Social Touch Hypothesis', touch received from another individual is imperative for social communication, human development, and close social bonding. This is due to touch involving positive, physical interaction with others (Brauer et al., 2016; Cascio et al., 2019; Morrison et al., 2010; von Mohr et al., 2017). The more experience of touch an individual receives from another, the greater the relationship and bond formed between them and the touch provider (Gallace & Spence, 2010).

As demonstrated in previous investigations, the skin is an important organ of the body which plays a key part in touch and in particular, interpersonal touch (Field, 2010). The smoothness and softness of the skin can determine whether touch is perceived as pleasant or unpleasant (Guest et al., 2009). In Guest et al.' (2009) study, ratings were made of one's own skin and the skin of others for both the forearm and palm for smoothness, softness, stickiness, and pleasantness. Surprisingly, in this study, one's own skin was rated less pleasant to touch than the skin of another person. For both touch to the self and touch from another, the forearm was rated as smoother, softer, less sticky and as such rated as more pleasant consequent to these properties than the palm. In their experiments, the pleasantness of touched skin was associated with the skin's perceived smoothness and softness and negative associations with its perceived stickiness (Guest et al., 2009). In a second experiment, when skin emollients were applied to the palm, touch received from the palm was actually rated as more pleasant than touch to the forearm. Thus, texture of skin can affect the pleasantness of touch and the emotions that are experienced from that touch. For example, if the skin of another is not very pleasant, this may negatively impact how the receiver interprets this type of touch and the pleasantness derived from this touch (Ramachandran & Brang, 2008).

1.2.2 The C tactile system: A specialised pathway for affective touch

In the skin, low threshold mechanoreceptors are innervated by myelinated Aβ afferent nerves which enable fast processing of stimuli applied to the skin. This is due to their fast conduction i.e., they have conduction velocities of 20-80 m/s, to allow for the rapid discrimination of touch. Whereas in the hairy skin, such as the face and arm, there are fewer fast conducting low threshold mechanoreceptors and instead there are more unmyelinated low-threshold mechanosensory nerves, referred to as C low-threshold mechanoreceptors in animals or C-tactile afferents (CTs) in humans, which have an emotional function (Walker et al., 2017). The rate at which these unmyelinated mechanoreceptors conduct is fifty times slower compared with myelinated Aβ afferents. These mechanoreceptors optimally respond with conduction velocities of 0.5-3 cm/s (McGlone et al., 2014; Olausson et al., 2010). However, repeated brushing of gentle touch can lead to a reduction of the firing of these afferents, demonstrating that these afferents are prone to fatigue (McGlone et al., 2014). Not only do CTs respond to specific velocities, but they also respond at certain temperatures (Ackerley et al., 2014), as they respond optimally at skin temperature, rather than with warmer or colder temperatures (McGlone et al., 2014). Overall, it has been revealed that CT fibres constitute towards the most prevalent afferent present in the skin of all mammalian species (Griffin et al., 2001).

Previous research focusing on animal models have offered support for unmyelinated CTs which innervate hairy, but not glabrous skin, using molecular genetic visualisation with adult mice (Liu et al., 2007; Li et al., 2011) and various other mammalian species (Bessou et al., 1971; Douglas & Ritchie, 1957; Iggo & Kornhuber, 1977; Kumazawa & Perl, 1977). In humans, microneurography, involving the study of a single peripheral nerve fibre, has been used to determine the rate at which CTs fire and has identified that this firing correlates with subjective pleasantness of slow, gentle touch (Johansson et al., 1988; Löken et al., 2009; Nordin, 1990; Watkins et al., 2021).

Therefore, it is hypothesised that the affective component of touch is facilitated by the activation of low-threshold mechanoreceptors, C-Tactile (CT)-afferents, found in hairy, but not glabrous skin (Ackerley et al., 2014; Liu et al., 2007; McGlone et al., 2012; McGlone et al., 2014; Woodbury et al., 2001). CT-afferents optimally respond to gentle stroking velocities ranging from 1-10 cm/s (Löken et al., 2009). It is these velocities in which touch is rated as most hedonic, with an inverted U-shaped relationship between stroking velocity and CT mean firing frequency, with the peak of CT activation and greatest pleasantness rating occurring at 3 cm/s and reduced responses at 0.1 cm/s and 30 cm/s (Ackerley et al., 2014; Löken et al., 2009; McGlone et al., 2014). It had been found, through neuroimaging investigations, that this system is facilitated by the activation of the Somatosensory Cortex, a brain region involving the discrimination of the location on the body an individual was touched (Gazzola et al., 2012; McGlone et al., 2012; Olausson et al., 2002) (See section 1.2.3).

1.2.3 Brain regions involved in affective touch

Previous research has offered insight into the cortical brain regions associated with CT stimulation through gentle stroking of hairy skin (Gordon et al., 2013; Löken et al., 2009; Löken et al., 2011; Olausson et al., 2008; Olausson et al., 2010; Vallbo, et al., 1999; Vallbo et al., 1995; Wessberg et al., 2003; Wijaya et al., 2020). A plethora of investigations have highlighted that CT-optimal touch generates activation in the affective/rewarding brain areas (Gordon et al., 2013; McGlone et al., 2012; Olausson et al., 2002; Trotter et al., 2016). In particular, a large number of studies have highlighted that the Insula Cortex, specifically the dorsal posterior Insula Cortex, is activated when an individual is experiencing actual affective touch to the hairy skin of the arm (Björnsdotter et al., 2009, 2011; Gordon et al., 2013; Jonsson et al., 2017; Morrison, 2016) and also with the anticipation of the sensations of future affective touch (Craig, 2002). The posterior Insula is thought to be sensitive to the velocity of the stroking touch and has been found to be most responsive to a velocity of 3 cm/s (Björnsdotter et al., 2011; McGlone et al., 2012; Morrison et al., 2008), with the anterior region playing a key role in CT pleasantness sensitivity (Kirsch et al., 2020). The Insula Cortex is the recipient of input from internal bodily states, contributing to interoceptive processing (Craig, 2002; Kirsch et al., 2020) and the processing of affective touch, as affective touch is a sub-modality of interoception. Thus, it is suggested that the Insula involvement is to convey the affective and affiliative aspects of this type of social touch (Krahé et al., 2018).

As well as the Insula Cortex, neuroimaging investigations have highlighted the involvement of key networks involved in social perception and social cognition (Gallagher & Firth, 2003; Gordon et al., 2013; Koster-Hale & Saxe, 2013; Voos et al., 2013). These areas include the posterior superior temporal sulcus (pSTS), medial Prefrontal Cortex (mPFC), the Orbitofrontal Cortex (OFC) and the amygdala (Gordon et al., 2013; McGlone et al., 2012; Voos et al., 2013). In support, Björnsdotter et al. (2014) conducted a functional magnetic resonance imaging (fMRI) investigation, in order to assess which brain regions respond to actual gentle brush stroking to the palm and hairy body parts such as the forearm. It was revealed that the primary somatosensory cortex, secondary somatosensory cortex, insular cortex, and right posterior superior temporal sulcus (pSTS) were significantly activated for all groups of participants (children, adolescence, and adults). A functional near-infrared spectroscopy (fNIRS) investigation revealed activation of pSTS during CT-targeted touch using brushing to the right forearm compared to palm (Bennett et al., 2014). Findings from an fMRI investigation identified a positive correlation between stroking touch pleasantness ratings and pSTS activation (Davidovic et al., 2016). Gentle stroking has also been associated with mPFC activation (Chen et al., 2020; Gordon et al., 2013; Voos et al., 2013), and specifically the ventromedial Prefrontal Cortex (vmPFC) (Davidovic et al., 2019), an area involved in early social cognition. Specifically, the mPFC is important for human social cognition and behaviour. The mPFC is well known for its involvement in theory of mind (perspective taking) and mentalising abilities and is implicated in inferring other people's intentions and mental states, as well as attributing emotional states to others (D'Argembeau et al., 2007; Sperduti et al., 2011). Greater mPFC activation has previously been identified following manual brush stroking to the arm, compared to the palm (Gordon et al., 2013). As suggested by Gordon et al. (2013), coactivation of the amygdala, Insula and mPFC during CT touch might represent the encoding of the social relevance and reward of that touch. These investigations offer support for the involvement of both interoceptive and exteroceptive modalities when processing touch and the involvement of social cognitive brain regions, due to the social meaning of this type of touch.

Furthermore, regions involved in the discrimination of touch, specifically the primary Somatosensory Cortex (S1), a region involved in thresholds of tactile detection (Cohen et al., 1991), discrimination of temporal frequency (Knecht et al., 2003), two-point discrimination (Tegenthoff et al., 2005), and discrimination of tactile direction (Lundblad et al., 2011), has been under dispute of its involvement in affective touch (Case et al., 2016). For example, Case et al. (2016) used fMRI and repetitive Transcranial Magnetic Stimulation (rTMS) to examine the role of S1 in processing touch intensity and pleasantness during brushing of the hand. After participants received rTMS over S1, sensory discrimination was reduced and subjects with reduced sensory discrimination rated touch as more intense, but pleasantness ratings were not affected. Furthermore, research concerning patients who lack Aβ-afferents (mechanoreceptors involved in rapid discrimination of touch) (McGlone et al., 2014) and have intact CT-afferents lacked touch discrimination, yet demonstrated typical Insula responses and self-reported pleasantness ratings when their hairy skin was stroked at CT-optimal speeds (Olausson et al., 2002, 2008). Therefore, findings from this research suggest that S1 is not involved in affective aspects of touch but only discriminatory aspects of touch. Despite research providing evidence that pleasantness of touch is processed outside of S1, several investigations have revealed correlations between ratings of touch pleasantness and S1 activation (McCabe et al., 2008; Gazzola et al., 2012). Yet, although the case, these studies did not use CT-optimal touch in their investigations and so make it difficult to draw conclusions that S1 plays a key role in affective touch.

Overall, as previously stated by Björnsdotter et al. (2014) and Hagberg et al. (2019), the brain regions surrounding the reprocessing of touch is not fully understood and requires further investigation, as research has linked a multitude of brain regions to affective touch processing. Therefore, future studies are required in order to assess the exact brain regions involved and the role they play in the processing of touch and whether brain regions involved in social cognitive processing are also required when processing touch to the skin.

1.2.4 Different modalities of touch: Affective Touch vs Discriminatory Touch

Not only is affective touch a modality of touch, but the sense of touch is also comprised of another sub-modalities which is discriminative touch i.e., localising external touch stimuli. Discriminatory touch is involved in the perception of pressure, vibration, and texture of a stimulus. This system is rapid in response and any signals sent through this system is processed with importance. The main function of the system is to detect touch from a stimulus, discriminate the touch that has been received and identify the stimulus which has touched the skin. These are key in making rapid decisions and guiding behaviour (McGlone et al., 2014), if the stimulus is hot and from an object which can burn the skin, the response from the system will result in the individual rapidly moving away from that stimulus. This system involves a series of low threshold mechanoreceptors (LTMs), such as fast adapting receptors i.e., Meissner's Corpuscles and Pacinian Corpuscles and slowly adapting receptors, such as Merkel's Disks and Ruffini Endings. All of these receptors convert applied forces on the skin into large A-beta (Aβ) myelinated afferent nerve pulses (Kandel et al., 2013; McGlone et al., 2007, 2014). Meissner's Corpuscles and Merkel's disks are found deeper in the skin's dermis, whereas Pacinian Corpuscles and Ruffini Endings are found closer to the skins surface (McGlone et al., 2007, 2014).

As mentioned previously, a second modality of touch is the affective-emotional component (McGlone et al., 2014). The human skin is innervated with various tactile afferents, with varying densities across the body (Ackerley et al., 2014). Affective touch has been linked to a neuro-physiologically specialised system, referred to as the C-tactile (CT) system (for visualisation see Figure 1.2.3.1). Research has revealed that it is slow, gentle stroking applied to the hairy part of the skin (CT-innervated body sites), which is generally perceived as pleasant and rewarding, particularly by healthy individuals (Ackerley et al., 2014; Croy et al., 2016; Essick et al., 1999; Löken et al., 2009, 2011; Olausson et al., 2008; Olausson et al., 2010; Vallbo et al., 1999; Vallbo et al., 1995; Wessberg et al., 2003; Wijaya et al., 2020). Affective touch is generally perceived as pleasant across the lifespan, regardless of the age of the receiver (Croy et al., 2016; Sehlstedt et al., 2016). Research conducted by Croy et al. (2016) found that children between the ages of 5-8 and 9-12 preferred and rated CT-optimal affective touch as more pleasant compared to CT non-optimal touch. Likewise, similar findings were also discovered in Jonsson et al. (2017) investigation, where preference for gentle, affective touch was observed in two-month-old infants, who received touch to the forearm. Furthermore, Ackerley et al. (2014) revealed that after applying soft brush stroking to adults across the skin at 5 body locations (forehead, arm, palm, thigh and shin) given at 5 velocities (0.3 cm/s, 1 cm/s, 3 cm/s, 10 cm/s and 30 cm/s), it was between 1-10 cm/s that was perceived as most pleasant for all skin regions apart from the palm, which is not a CT-innervated area (Ackerley et al., 2014; Essick et al., 1999; Essick et al., 2010; Guest et al., 2009; McGlone et al., 2012).

1.2.5 The links between interoceptive and exteroceptive modalities with affective touch

In recent years, research has focused on the role interoception in body ownership and sense of self (Crucianelli et al., 2016). There is a classic distinction between exteroception and interoception i.e., sensation of an object in the external environment vs. the body itself as an object. There may be unique and dissociable anatomical pathways underlying each, derived from stimulation of distinct tactile receptors (Sherrington, 1906). In particular, the overlapping central projections of CTs to the posterior Insula, as this pathway is similar to that of visceral afferents, CT afferents have more in common with interoceptive systems conveying information about body state regulation than with classical exteroceptive systems conveying discriminative aspects of touch (Björnsdotter et al., 2010). Interoception is defined as the physiological condition of the internal state of the body (e.g., cardiac, respiratory, or digestive) and from the outside of the body (e.g., temperature, itch, pain, and pleasure of touch) (Craig, 2002). Interoception compromises of two forms of perception: proprioception which is signals deriving from the skin and the musculoskeletal system and visceroception involving the signals that come from inner organs such as heart rate and hunger (Fischer et al., 2016). Interoception is a process involving the awareness of bodily sensations which inform the individual about their bodily needs (Craig, 2009; Seth, 2013). Therefore, interoception assists with ensuring stability of the individual through sensations such as hunger and thirst and interoceptive awareness is an important process for body image (Ainley et al., 2012; Craig, 2009; Critchley et al., 2004; Todd et al., 2020). Todd et al. (2019) conducted a study involving the administration of a plethora of questionnaires that measure both Interoceptive awareness and body image such as Multidimensional Assessment of Interoceptive Awareness (MAIA), the Body Appreciation Scale-2, the Functionality Appreciation Scale, the Authentic Pride subscale from the Body and Appearance Self-Conscious Emotions Scale, and the Appearance Orientation and Overweight Preoccupation subscales from the Multidimensional Body-Self Relations Questionnaire. It was revealed that interoceptive awareness accounted for all 5 facets of body image such as body appreciation, functionality appreciation, body pride, appearance orientation and weight preoccupation. Thus, this study offers support for the connection between interoceptive awareness and body image. Similarly, Zamariola et al. (2017) explored the relationship between interoceptive accuracy and the external perception of the body by using the heartbeat counting task, which requires participants to count their heartbeats in a given time frame, without using their pulse as a measure, whilst the actual number of heartbeats are recorded by the researcher. The discrepancy between the actual number of heartbeats recorded and the number reported by the participant is calculated. In addition, the Body Image Revealer (BIR) (exteroceptive task) in which a fully body image of a participant is taken and displayed to participants. This image is also manipulated to be larger and smaller than the participants actual body size. Participants are probed to respond to questions concerning which image they think they look like, what they want to look like, how they feel they look like and how they think others view them. It was revealed that participants with lower interoceptive accuracy demonstrated significant improvements in interoceptive accuracy following the exteroceptive task (Zamariola et al., 2017). Therefore, interoception plays an important role in healthy body representation and bodily awareness (Gentsch et al., 2016; Zamariola et al., 2017).

As well as interoceptive awareness, exteroceptive awareness is fundamental in the interaction of an individual with their surrounding environment and both together provide an individual with information about the touch they have received and sense of self

(Badoud & Tsakiris, 2017; Crucianelli et al., 2016; Suzuki et al., 2013; Tsakiris et al., 2011). There have been several accounts put forward which suggests that touch and the socio-emotional understanding of touch involves both interoceptive and exteroceptive modalities (Crucianelli & Filippetti, 2020; Ebisch et al., 2011). First, an exteroceptive modality activates the primary and secondary somatosensory cortices. This provides information about the physical characteristics of a stimulus on the skin such as weight and texture for a prompt response. For touch, this will provide information concerning the velocity and weight that touch is given (Penfield & Boldrey, 1937; Trulsson et al., 2001; McGlone et al., 2002). After which, an interoceptive (affective) modality provides information about the affective states that have been driven from the tactile stimulation such as the hedonic/pleasure feelings associated with receiving this touch (Björnsdotter et al., 2009; Craig, 2002; Olausson et al., 2002). Yet, Crucianelli et al. (2016) investigated the relationship between interoceptive (i.e., cardiac awareness, affective touch) and exteroceptive modalities in body awareness. The results did not offer confirmation of a relationship between interoceptive sensitivity and the perception of affective touch, nor any strong influence with body ownership. However, research investigating the possible link between interoceptive and exteroceptive modalities is in short supply. Furthermore, findings from previous research are controversial as to whether both modalities are required for the processing of affective touch. Therefore, more research investigating the role both modalities play in conjunction with one another during the processing of affective touch is required.

1.2.6 Directly felt vs. vicarious experience of affective touch

The hedonic experience of affective touch can be broken down into the observation (vicarious experience) and actual experience of touch which are a regular occurrence in everyday situations in social settings such as observing one person touching another, direct touch from another person and also during the observation of natural scenarios, such as a truck touching a tree branch whilst driving past (Ebisch et al., 2008).

Observing someone receiving touch first initiates visual processing of the stimulus, this is then proceeded by a cognitive account of the meaning of the stimulus received i.e., what the affective states of the two people exchanging touch are feeling and as such requires another level of social cognition such as Theory of Mind (ToM). This requires perspective taking through comparing oneself (1^{st} person perspective) to the state of another individual (3^{rd} person perspective), which is dependent upon ones bodily awareness and past experiences (Cooper & Mohr, 2012).

As outlined by models of embodied stimulation, the same neural networks involved in our own direct bodily experiences are also similarly involved when we observe the world, which occurs due to a visuo-tactile mirroring mechanism (Gallese, 2005, 2006; Gallese & Lakoff, 2005). During the observation of touch, the same regions involved in actual experiences of touch are also activated and the same internal sensations associated with the touch. This is due to an automatic mirroring and internal simulation of the touch being perceived, which is initiated by the mirror neuron system and our own somatosensory systems (Keysers et al., 2004; Gallese, 2009; Rizzolatti & Craighero, 2004). For example, regions such as the somatosensory cortices, Insula Cortex and the parietal operculum which are activated also when someone is directly experiencing actual touch (Blakemore et al., 2005; Ebisch et al., 2008; Keysers et al., 2004, 2010; Masson et al., 2018; Pihko et al., 2010; Schaefer et al., 2012). These regions are triggered during the vicarious experience of an object being touched (Keysers et al., 2004). Thus, it does not matter if a person or object is being touched, these both share the same neural circuits (Ebisch et al., 2008). On the other hand, an fMRI investigation by Ebisch et al. (2011) revealed a differentiation in the activation of the posterior Insula between direct and observed touch, with this region being more largely involved in the direct experience of touch. Therefore, this study highlights the inconsistencies regarding activation of regions during actual and observed touch. In particular, the role of the somatosensory cortex in touch observation has been controversial and remains under debate (Masson et al., 2018).

Moreover, it has been revealed that the brain is wired to predict responses to different types of touch, both observed and actual touch, which specifically involves the pregenual anterior cingulate cortex (pgACC; Scalabrini et al., 2019). The predictive coding framework outlines that the brain is like a predictive machine and that these predictions are used in order to alter behaviour (Daw et al., 2005). In order to achieve this, the brain uses top-down signals of previous information in order to make these predictions. If the predictions made is different from the bottom-up signals of new incoming information then this generates a prediction error. The brain then uses this error to update the response or to update the prediction for future occurrences (Spratling, 2017). This predictive framework can be used in relation to the explanation of comforting touch responses as the brain is constantly making predictions about the expected homeostasis (maintaining the body in a state of equilibrium) (Burleson & Quigley, 2021). Touch can be considered a response at reducing distress and homeostasis is the predictive outcome i.e., the reward associated with the touch received (Shamay-Tsoory & Eisenberger, 2021). When the touch received does not reduce distress as anticipated, a negative prediction error is generated. It is these prediction errors which constantly update the touch responses i.e., there is a mismatch between the expected outcome of the touch received and the actual outcome of the touch received. These updates in predictive errors occur over periods of time of touch interactions (Shamay-Tsoory & Eisenberger, 2021). With regards to shared representation of social touch, if the prediction is different from the other's distress then this generates a prediction error. If a distress is detected this activates observation execution systems such as the inferior frontal gyrus, inferior parietal lobule, and premotor cortex, touch systems which includes the primary and secondary somatosensory cortex and the shared distress systems such as the dorsal anterior cingulate cortex and the anterior insula. If distress was not detected then this activates the homeostasis reward system which comprises of the orbitofrontal cortex, ventromedial prefrontal cortex, and the ventral striatum (Shamay-Tsoory & Eisenberger, 2021). Therefore, if negative predictive errors are regularly generated and the brain uses these errors to update future predictions, this predictive framework could offer a potential explanation for the negative responses to touch in relation to eating disorders, as Crucianelli et al. (2021) found that negative experiences to affective touch in individuals with AN occurred in relation to the anticipation of affective touch (see chapter 1.3.7).

1.2.7 Self vs. Other-directed social touch

The observation of touch and the actual experience of touch is comprised of both touch directed towards the self (self-directed touch) and touch given to another person (other-directed touch). Self-directed touch is believed to be vital for self-awareness and important to the distinction between self and others (Boehme et al., 2019; Lesur et al., 2021; Schütz-Bosbach et al., 2009). This distinction is essential for interactions in the social environment (Boehme et al., 2019). This type of touch is also important for neurotypical development (Rochat & Hespos, 1997). Self-touch has shown to have positive benefits relating to internal bodily awareness i.e., interoception and self-regulation when practiced over a period of time (Matiz et al., 2020). This type of touch occurs unconsciously and on a regular basis (Rahman et al., 2020). However, touch directed towards the self not only involves self-touch but also touch delivered from another person to the self. Touch directed towards the self which has been delivered from another individual is important in social bonding and communication (Boehme et al., 2019), with this type of touch activating regions largely associated with social cognition and regions such as the Insula Cortex and pSTS (Gordon et al., 2013; Morrison et al., 2011).

Moreover, in relation to other-directed touch, it has been reported that viewing others being touched induces vicarious touch experiences, which is based on the recruitment of brain regions, which originally were responsive to first-hand somatosensation, including the somatosensory cortex, the parietal operculum and the insular cortex (Blakemore et al., 2005; Ebisch et al., 2008; Schaefer et al., 2012; Morrison et al., 2011). It has been reported that when individuals observe touch, the observer also experiences the touch they are perceiving to that specific body part (Banissy & Ward, 2007). For example, when observing someone receiving touch to the cheek, this generates the sensation that the observer is also experiencing the same tactile stimulation on their cheek (Serino et al., 2008). This shared representation of tactile experience has shown to be diminished when somatosensory activation is inhibited using TMS (Fiorio & Haggard, 2005). In conjunction with this shared representation, it has been previously demonstrated that ratings of vicarious touch have the same relationship between velocity and anticipated pleasantness as directly felt self-directed touch (Walker et al., 2017). It is important to note that this experience of observing someone else receiving touch is unconscious and occurs automatically (Maister et al., 2013).

1.2.8 The importance of Touch

Physical contact through touching behaviours is a basic human requirement as the type of interaction has emotional, mental, and physical benefits (Tejada et al., 2020). After birth, a child will continue to receive touch from their mother or a caregiver through breastfeeding and from parents or caregivers through direct skin-to-skin contact such as hugging and cradling (Ferber et al., 2008). Touch during childhood is particularly vital for healthy growth and development and has been found to have rewarding values, such as soothing and calming effects when a child is experiencing pain or discomfort (Bellieni et al., 2007).

Discriminatory touch is also important for developing fine motor movements, as touch in early childhood is largely used for learning and understanding the grasping and rewarding aspects of certain objects. When a child holds an object, touch generates crucial information about texture, firmness, and temperature of this object, allowing a decision to be made as to whether this object is rewarding or could pose harm (Field et al., 2010; Sann & Streri, 2008). When an infant reaches 6 months of age, they demonstrate refined object-orientated motor responses in order to be able to manipulate objects (Corbetta & Snapp-Childs, 2009). They use previous experience of sight, reach and grasping in order to guide their motor movements with different types of objects.

To further support the importance of touch in development, research focusing on touch deprivation non-human animals, adults and in infants have demonstrated how important touch is for positive development (Carozza et al., 2021; Devine et al., 2020; Fleming et al., 2002; Walker, 2010). For example, Harlow and Zimmerman's (1958) study focusing on maternal separation and isolation in rhesus monkeys demonstrated that touch from a mother is important for emotional development, as these monkeys clung to surrogate cloth mothers for comfort when in times of distress. In further support, Zazzo (1975) revealed that chimpanzees who were reared in isolation from their mothers, demonstrated the inability to recognise themselves in a mirror as opposed to those raised typically. This study highlights the importance of touch in development of self-awareness. Furthermore, children in care who typically receive less touch from caregivers as opposed to children not in care, display later cognitive, and neurodevelopmental impairments and delays (Chugani et al., 2001; Kadlaskar et al., 2019; MacLean, 2003). These children display neuro-developmental and cognitive skills which are below average compared to children raised in parental homes and those in care still display these delays even after years in adoption, regardless of whether the child receives more touch than they did in care (Beckett et al., 2006).

In addition, children of depressed mothers also experience touch deprivation (Field, 2001). As supported in the research conducted by Herrera, Reissland and Shepherd (2004) those children who have depressed mothers compensated for their lack of touch by significantly touching themselves more positively, compared with children with non-depressed mothers. Also, children of depressed mothers use active types of touching such as grabbing, patting, and pulling when in stressful situations as a calming mechanism for themselves (Moszkowski et al., 2009).

Touch deprivation, resulting in developmental delays, can also occur from mothers of high-risk infants, such as babies with low birth weight, premature babies or those children born with complication requiring intensive treatment, as these babies experience significantly less touch compared to children born with healthy weights and no complications. Research conducted by Weiss, Wilson, and Morrison (2004) found that if high-risk children receive touch such as massage from their mothers, then this will compensate for the infants' developmental delays. Also touch from mothers of premature babies has also been found to help with short-term stress by reducing cortisol levels (Neu, Laudenslager, & Robinson, 2009).

Touch is not only beneficial for the infant (the receiver of touch), but also has beneficial impacts for the mother (the initiator of touch), which is not only applicable for attachment with their child. Research has found that mothers who are depressed also show beneficial signs of reduced depression consequent to an increase in touch given to their child (Field et al., 1996; Ferber, 2004; O'Higgins et al., 2013). In Neu et al. (2009) study, touch also helped in decreasing cortisol levels for the mother as well as the infant. Thus, highlighting the positive impacts touch that massage has for both the child (individual who receives touch) and the mother (individual who initiates the touch).

Not only is touch important for early human development (Bellieni et al., 2007) and the establishment of fine motor skills when interacting with objects (Corbetta & Snapp-Childs, 2009), touch is also crucial for social interactions. Touch can be used as a form of non-verbal communication which can depict different emotions, without the need of facial expressions (Kirsch et al., 2018). The emotion that is conveyed is dependent upon the touch that is provided such as the velocity, distance, and body region this touch is given to. Touch is a strong form of non-verbal communication in that facial expressions are not required in order to convey an emotion to another (Elfenbein & Ambady, 2002). For example, in Hertenstein et al. (2006) study, participants were assigned to a role which was either the sender, who used touch on another's forearm to express an emotion or where the receiver who had to sit behind a curtain, so no visual cues were present and guess the emotion based on the touch. These emotions included happiness, sadness, surprise, disgust, anger, fear, sympathy, love, pride, envy, and gratitude. It was revealed that touch was used in different ways to prompt different emotions and the receivers were able to identify the emotions they were receiving (accuracy ranging from 48% to 83%), with a range similar to what is found in facial and vocal expression studies (Elfenbein & Ambady, 2002). Examples of the touch to receivers included pushing, lifting, and tapping to signify a disgust emotion and hitting, squeezing, and trembling to express an angry emotion. Accuracy scores were higher in a further study where senders were able to use an appropriate part of the body to express the emotion they were conveying (Hertenstein et al., 2009). Thus, emphasising that touch, regardless of whether this is from a stranger or someone you know, can generate different emotional cues, depending on the way in which that touch is initiated (Hertenstein et al., 2006, 2009). However, results from these studies have limited application, particularly in areas where touch is limited or is restricted all together (Field, 2010).

Touch is also important in the development of romantic relationships particularly with relationship and partner satisfaction (Goff et al., 2007; Gulledge & Fischer-Lokou, 2003). The way in which touch is expressed for this type of relationship is different, as this type of touch typically involves the holding of hands, hugging, kissing, cuddling, caressing, and massaging. It is the absence of this touch which is believed to result in lack of development in this relationship (Gulledge & Fischer-Lokou, 2003). Yet, it is also important to note that the way in which touch is used in social interactions and in relationships differs depending on cultures (Field, 2001).

Given the overall importance of touch in development, it has been proposed that the lack of pleasantness sensations associated with social interactions (Tchanturia et al., 2012), specifically affective touch in AN (Crucianelli et al., 2016, 2021; Davidovic et al., 2018), could account for atypical interpersonal and social cognitive functions, which could be linked to the onset and maintenance of this eating pathology (Arcelus et al., 2013; Castro et al., 2010; Zucker et al., 2007) (See Chapter 1.3 below).

Chapter 1.3

An impaired affective touch system and the links with body image disturbances in Anorexia Nervosa (AN)?

1.3.1 Definition and criteria of Eating Disorders

As outlined in the Diagnostic and Statistical Manual of Mental Disorders 5 Test Revision (DSM V- TR; APA, 2022) and outlined in Table 1.3.1.1, eating disorders are a group of pathologies which all share various characteristics in common such as abnormal eating behaviours. Patients with this disorder display an unhealthy fixated concern and obsession towards their body shape and weight leading to severe body image disturbances. Due to this, patients with an eating disorder experience significant impairments in their physical health and social functioning. There are 3 main classifications of an eating disorder; ;“Anorexia Nervosa” (AN), “Bulimia Nervosa” (BN) and “Binge Eating Disorder” (BED) (APA, 2022). As reported in the DSM 5, both AN and BN share common characteristics such as overevaluation of weight and body physique, which leads to extreme eating behaviours to control their weight such as food intake restrictions for individuals with AN, excessive purging or abuse of laxatives and dietary medications for BN and compulsive exercise for both. Both conditions involve patients having a strong fixation on to maintaining a thin body shape, leading to greater body dissatisfaction and concerns. Patients who have AN tend to maintain an extremely low body weight ranging from mild (BMI $\geq$ 17 kg/m^2) to extreme (BMI < 15 kg/m^2). To achieve this, they will engage in self-starvation. On the other hand, patients with BN engage in binge eating behaviours in order to purge and tend to possess healthy weight levels. On the other hand, BED involves excessive and uncontrollable consumption of food without the intention of purging. These patients do not possess any form of body image concerns, unlike individuals with AN and BN (APA, 2022; Hay, 2020).

As well as eating disorders, DSM 5 have identified various feeding disorders such as “Avoidant/Restrictive Food Intake Disorder” (ARFID), which involves the lack of intake of food or the consumption of very small amounts of food. Furthermore, “Rumination Disorder” involves an individual repeatedly regurgitating their consumption of food at least for 1 month, which is either re-chewed, re-swallowed or spat out and is not caused by a gastrointestinal condition. This disorder occurs due to stressful situations and lack of stimulation. However, not all eating and feeding disorders involve consumption of food. “Pica” has been defined as another form of eating disorder, in which an individual engages in atypical persistent eating of non-food substances such as plastic, grass, chalk etc. over a period of a minimum of 1 month (APA, 2022). Pica does not include the consumption of dietary products such as protein shakes. The risk for this disorder is mainly environmental such as neglect and crucial development delays (APA, 2022). Unlike AN and BN, ARFID does not involve a form of body image concerns, instead is an eating disorder largely characterised by avoidance and aversion to food and its consumption. This disorder largely manifests during infancy and may persist throughout adulthood (APA, 2022; Hay, 2020).

Furthermore, two additional eating and feeding disorders have been identified, specifically categorised as “Eating Disorder Not Otherwise Specified” (EDNOS) these include “Other Specified Feeding or Eating Disorder” (OSFED) and “Unspecified Feeding or Eating Disorder” (UFED). Both of these diagnoses are given to an individual who does not meet the full criteria for an eating or feeding disorder. OSFED is diagnosed when an individual meets enough criteria for an eating disorder but does not meet all. Patients classified as having OSFED experience an impaired social functioning, purging and night eating syndrome (Qian et al., 2022). UFED is identified when there is not sufficient evidence to specify the eating disorder diagnosis. It has been found that the negative psychological impact caused by EDNOS is as severe as both AN and BN (Thomas et al., 2009).

Typically, eating disorders tend to have comorbidity with other pathologies such as Autism Spectrum disorder, Schizophrenia, Obsessive-compulsive disorder, Bipolar disorder, Depression and Generalised Anxiety disorder. In addition, some eating disorders show conjunction with Trichotillomania (hair pulling) disorder, Excoriation (skin picking) disorder and intellectual disability (APA, 2022).

Importantly, it should be noted that the criteria for an eating disorder is more female orientated as until recently, it was believed that eating disorders were more of a female disorder, meaning that males were underrepresented particularly in the clinical research field. Nevertheless, at present, this is not the situation, as males are receiving more attention due to the increase in eating disorders being reported (Strother et al., 2012), with amenorrhea no longer being considered a key criterion in the diagnosis of AN, as this criterion does not apply to males (APA, 2022; Gorrell et al., 2019).

Table 1.3.1.1 The Key diagnostic characteristics associated with the main eating disorders according to the DSM 5-R criteria.

	Anorexia Nervosa	**Bulimia Nervosa**	**Binge Eating Disorder**	**Avoidant/restrictive food intake Disorder**
Eating behaviours	Extreme restrictive eating behaviours	Skipping meals, eating excessive amounts in order to purge	No restriction of food intake and eating until feeling uncomfortably full	Extreme restriction of all food or of particular foods
Binge Eating	Occasionally	Regular in order for purging behaviours	Episodes occur on a regular basis	No such behaviour engaged
Weight	Severely Underweight	Healthy or above this range	Healthy or above this range	Severely Underweight due to significant weight loss
Body checking and body image avoidance	Constant body checking and overvaluation of body size. Pre-occupation with the fear of gaining weight	Overvaluation of body size	Can display overvaluation of body size	No overvaluation of body size occurs

Feelings	Low mood, anxiety, and high levels of shame	High levels of bodily shame present	Distressed, disgusted, guilty, depressed, low self-esteem	Low mood, anxiety, and high levels of shame
Purging, fasting, excessive exercise for weight control	One or more of these behaviours are present	Regularly and use of medications i.e., laxatives to prevent weight gain	Not regularly occurring	Do not engage in any of these behaviours
Social behaviours	Isolation, withdrawal, and social avoidance	Isolation, withdrawal, and social avoidance	Eating alone due to feeling of embarrassment associated with high volumes of food consumed	Interference with their psychosocial functioning resulting in social isolation

1.3.2 Prevalence and Mortality Rate of Eating Disorders

Eating disorders are predominantly reported in Western countries, with the majority of cases being women, which is suggested to be due to cultural ideals and beliefs (Makino et al., 2004), with lifetime prevalence rates being greater than disorders such as Schizophrenia (Qian et al., 2022). The reported number of eating disorders worldwide is believed to be between 0.1% and 3.8% (Duncan et al., 2017; Qian et al., 2022). As outlined in the DSM 5, the proportion of women presenting symptoms of AN or BN in a 1-year time period is 0.4% for AN and 1-1.5% for BN. The prevalence of such eating disorders, however, is far less common in men compared to women, i.e., 1 in 5 (19.7%) females as opposed to 1 in 7 (14.3%) men experience an eating disorder by 40 years of age (Ward, 2019). Thus, there is a 10:1 female-to-male ratio of clinical populations with AN and BN (APA, 2013). AN, BED and OSFED are common eating disorders reported in the United States, with the majority of cases being in adolescents (Swanson et al., 2011). Furthermore, the highest prevalence of any eating disorder is for BED, with 2.8% of women and 1% of men. For AN, the lifetime prevalence is 1.4% for women and 0.2% for men and for BN 1.9% for women and 0.6% for men (Dahlgren et al., 2017; Galmiche et al., 2019). The age with the highest prevalence of an eating disorder diagnosis is 21 years of age for both males and females, with almost all cases in case review by Ward et al. (2019) been reported by the age of 25 years. It is believed that the prevalence rates for an eating disorder is increasing at a greater rate for males and that both males and females do not differ in the severity of their symptoms (Gorrell et al., 2019; Mitchison et al., 2014; 2015). Eating disorders result in an individual experiencing lower quality of life, increased cost for care and greater mortality rates (Agh et al., 2016; Arcelus et al., 2011). Nevertheless, it is unclear the prevalence rates of Pica and ARFID, due to the necessity for more research into these eating disorders (APA, 2013).

Moreover, it is important to note that eating disorders have the highest reported fatality rates compared to any mental health illness. This is consequent to the typical development of further complications, which could be due to the inability to cope, leading to greater risk of suicide and greater mortality rates. In particular, it has been reported that AN has one of the highest mortality rates of any mental health condition, reporting a significant 5-20% of cases (Smink et al., 2012; Qian et al., 2022), thus, 0.51% of AN patients die per year. The majority of deaths surrounding this condition occur due to complications associated with the disorder as opposed to suicide. BN has the lowest reported fatality of an eating disorder, with 0.17% patients dying per year as a result. Yet little is known about the mortality rates surrounding more newly discovered eating disorders such as Pica (APA, 2013; Smink et al., 2012). The prevalence rate of Rumination disorder is inconclusive but is common in individuals with intellectual disability (APA, 2013).

1.3.3 What is Anorexia Nervosa and what are the key features of this disorder

Anorexia Nervosa (AN) is an eating pathology characterised by body image disturbances, such as body image misperceptions, resulting in atypical eating behaviours, dieting/fasting, fear of gaining weight, low energy intake and maintaining a low BMI as these individuals do not recognise that they are severely underweight. Individuals with

AN are unaware of their perceptual body image disturbances (DSM-V-TR; APA, 2022). In addition, individuals with AN display other deficits, for example hyperactivity (Kron et al., 1978), repetitive behaviours (Anderluh et al., 2003; Cassin & von Ranson, 2005), mood disturbances (Blinder et al., 2006) and difficulty with social cognition and developmental difficulties such as an inability to form attachments with others (Caglar-Nazali et al., 2014).

As suggested previously, a main feature in the maintenance of this eating pathology is body image perception disturbances (Beilharz et al., 2019; Buzzichelli et al., 2018; Cazzato et al., 2015, 2016; Esposito et al., 2018; Gadsby, 2017; Glashouwer et al., 2019; Legenbauer et al., 2020; Urgesi et al., 2014), which is associated with body image dissatisfaction and concerns (Friederich et al., 2010; Grilo et al., 2019). Individuals with AN classically display visual misperception of their body which is measured by using a size-estimation task (Cazzato et al., 2016; Cornelissen et al., 2013, 2015; Legenbauer et al., 2020; Mohr et al., 2010; Moscone et al., 2017; for review see Mölbert et al., 2017). Typically, when people with AN are asked to make estimates of their body size, they tend to show a significant overestimation in how they think they look like, compared to their actual body size (Cazzato et al., 2016, for review see Mölbert et al., 2017). Not only do people with AN overestimate the body as a whole, but they also tend to focus on body parts which are of a major weight concern (Toh et al., 2020) and demonstrate overestimations of these body regions, particularly to weight-sensitive body regions such as the abdomen (Keizer et al., 2011).

1.3.4 Limitations in the definition and treatment of Eating Disorders

As demonstrated in the DSM-5-TR, the criteria for an eating disorder demonstrate numerous commonalities in symptomatology, making it more difficult to diagnose and provide treatment for an individual with a specific disorder. It has been found that patients who are diagnosed with a specific eating disorder often display symptoms of another eating disorder (Castellini et al., 2011; Tozzi et al., 2005). In particular, this makes it really difficult to fully treat the disorder, resulting in lack of success in treatment interventions.

There have been many conventional treatments available for AN, with the first treatment offered being medications such as SSRIs or other antidepressants and antipsychotics, which are not 100% effective in treating this eating disorder (Claudino et al., 2006; Holtkamp et al., 2005; Marvanova et al., 2018; Vandereycken et al., 1984). As well as medications, various structured individual therapies have been developed for the treatment of AN, such as Cognitive Behavioural Therapy (CBT) and a more recently formed therapy referred to as the Maudsley Model of AN treatment for adults (MANTRA) (Schmidt et al., 2015), with the aim of changing food restrictive behaviours and weight-gain prevention behaviours (Muratore & Attia, 2021). MANTRA is a cognitive-interpersonal treatment, which is focused on the obsessive and avoidant behaviours of AN using reflection through patient-manual as key for changing behaviours (Schmidt et al., 2015). CBT is used to normalise eating behaviours and target the overevaluations of body shape and weight (Muratore & Attia, 2021). Both forms of therapy have been investigated in large clinical trials and have demonstrated very little effectiveness as a treatment of AN (Byrne et al., 2017; Schmidt et al., 2015, 2016; Treasure et al., 2020; Zipfel et al., 2014). In particular, CBT has low completion rates with just over half of patients completing their course of therapy (Byrne et al., 2011; Calugi et al., 2015; Fairburn et al., 2013). As well as individual structured therapies, family-based therapies have been made available which has shown to be more effective compared to individual based therapies 6 and 12 months after ending treatment (Lock et al., 2010; Muratore & Attia, 2021).

1.3.4.1 Touch therapy in the treatment of AN

A form of touch therapy in the treatment of AN, specifically body-oriented therapy involves achieving a balance between body and mind in order to improve well-being. This type of therapy involves the use of various exercises such as meditation, visualisation of the body, massage, sensation awareness (Leitan & Murray, 2014). Body-oriented therapy has shown to have beneficial impacts on symptoms associated with eating disorders (see Korsak et al., 2022, for a review).

One commonly practised form of body-oriented therapy includes massage therapy which has shown positive outcomes with eating disorder patients (Field et al., 1998; Hart et al., 2001). Massage therapy has largely been used as a successful treatment for stress in healthy individuals (Lindgreen et al., 2010) and health conditions such as pain disorders (Field et al., 2006), as touch is seen as a potential healing agent (Field, 2014).

AN symptoms such as body dissatisfaction, co-morbid anxiety and stress have also been found to be reduced, as well as evidence for an increase in dopamine and norepinephrine levels after receiving a course of massage therapy (Hart et al., 2001, 2011). Hart et al. (2001) assessed nineteen women diagnosed with AN who were given a standard treatment alone, compared to another group given standard treatment plus massage therapy for five weeks. It was revealed that the intervention group who received massage therapy, reported significantly lower stress and anxiety levels, and had lower cortisol hormone levels, which is the stress hormone, after receiving this therapy. Over five weeks of treatment, individuals with AN also reported decreased body dissatisfaction on the Eating Disorder Inventory and showed increased dopamine and norepinephrine levels (Hart et al., 2001). Thus, offering support for the beneficial effects massage therapy has on eating disorder symptoms. Yet, results from this investigation should be handled with caution, as some measures involved self-report and only one measure was used to assess levels of body dissatisfaction. Therefore, future studies should incorporate various measures in order to assess AN symptomatology improvement, which are believed to occur consequent to massage therapy. Also, more research is needed which focuses on the use of massage therapy in the treatment of AN and also in conjunction with another already established treatment intervention, to see whether consistent results are obtained regarding AN symptom improvement.

1.3.4.2 Non-invasive brain stimulation for treatment of AN

For eating disorders, to date, there is an extremely low number of investigations which have examined non-pharmacological treatments, such as the utilisation of non-invasive brain stimulation (NIBS) specifically repetitive Transcranial Magnetic Stimulation (rTMS) for treating AN (Woodside et al., 2021). rTMS is a technique which is commonly practiced in many clinics for treatment of disorders, due the ability of this technique to alter cortical excitability in target brain regions by stimulation i.e., delivering electrical pulses to these regions (Rawji et al., 2020). Nonetheless, the number of studies which have used NIBS on patients with AN is now gradually increasing and becoming a popular method of investigation (Duriez et al., 2020). For example, deep brain stimulation (DBS), which involves delivering electrical pulses to brain regions through implanted electrodes, has recently been proposed as a potential treatment for AN and has shown promising success rates (Godier et al., 2015). This method has potential to be used in the future for treatment of this disorder. Prior case studies of eating disorder patients who have received DBS have all demonstrated improvements in weight gain and eating disorder symptomatology, such as anxiety behaviours concerning the consumption of food (Blomstedt et al., 2017; Israël et al., 2010, for a review see Shaffer et al., 2023). Furthermore, Woodside et al. (2021) used rTMS to target the Dorsomedial prefrontal cortex (DMPFC) for 20-30 sessions to understand the neurobiological mechanisms involved in this eating pathology, as it is crucial to gain understanding of the functions of the brain regions that are believed to be associated with AN (McFadden et al., 2014), which TMS aims to achieve. This technique is becoming more popular due to the safety of using this neurophysiological practice when administered according to specific guidelines (Loo et al., 2008; Rachid, 2018; Rossi et al., 2021) For example, Costanzo et al. (2018) used transcranial direct current stimulation (tDCS) to target the Prefrontal Cortex to alter abnormal eating behaviours in patients with AN. These patients underwent usual treatment such as nutritional, pharmacological, and psychoeducational treatment, in addition to 18 sessions of tDCS. BMI, mood, and anxiety symptoms were assessed pre and post treatment, where it was revealed that patient's experienced significant weight gain post treatment (McClelland et al., 2018). Yet, on the contrary, Khedr at al. (2014) revealed that only 3 patients out of 7 showed improvements in eating disorder symptoms immediately after treatment and one-month post tDCS treatment. Two patients only improved immediately after treatment and then returned to their baseline level of symptoms one month follow up. One patient only improved in one aspect of their symptoms and one patient did not show any signs of improvement in any symptoms (Khedr et al., 2014). Overall, suggesting that due to the controversial results this technique has demonstrated in improving AN symptomatology, it would be beneficial to use another brain stimulation technique such as repetitive TMS (rTMS) in future interventions.

Furthermore, as suggested by Batista (2019) excitatory repetitive rTMS appears to have a positive effect in changing eating disorder symptoms specifically related to eating behaviours when targeting brain regions such as the dorsolateral prefrontal cortex. Evidence from previous investigations have shown that TMS could be used as both a diagnostic and therapeutic technique for different neurological and psychiatric conditions (Habib et al., 2018) and has been used as a preferred method for many investigations with AN patients, due to the efficacy of this technique (Rachid, 2018). This is also consequent to the safety of using this technique to non-invasively alter brain functioning and does not cause any discomfort to AN patients and as such, they are able to tolerate this treatment (Rachid, 2018). The first reported rTMS intervention was conducted using a single-case report of a patient with AN, comorbid with depression. After receiving 41 sessions of rTMS over the left Dorsolateral Prefrontal Cortex (DLPFC), this patient demonstrated significant weight gain and reduction in depressive symptoms (Kamolz et al., 2008). In addition, many other single-case studies and investigations with multiple patients using rTMS to target the DLPFC have also demonstrated the success of this neurophysiological technique in reducing AN symptoms (Choudhary, Roy, & Kumar Kar, 2017; Jassova, Albrecht, Papezova, 2018; McClelland et al., 2013; McClelland, Kekic, Campbell, & Schmidt, 2016b; Van den Eynde et al., 2013). These studies illustrate that rTMS is a promising treatment intervention, as this technique has long lasting beneficial impacts on brain anatomy and functioning post-treatment (Croarkin et al., 2016), particularly when excitatory frequencies are delivered (≥ 5 Hz), which promotes the increase in the firing of cortical action potentials (Siebner & Rothwell, 2003). In particular, the more sessions of rTMS that is given over a longer period of time, the better the treatment outcome for patients with AN (Bartholdy et al., 2015; Dalton et al., 2018; Duriez et al., 2020). Nevertheless, targeting the DLPFC using rTMS has controversial findings, as in the study conducted by McClelland et al. (2016a) a non-significant difference was observed in the treatment and sham (control) conditions in AN symptoms. Symptoms of AN were not significantly reduced when compared to the sham condition (McClelland et al., 2016). Therefore, results from this investigation suggest that other brain areas should be targeted, as these regions may not be largely involved in the maintenance of AN symptomatology. Also, that it may be beneficial to target more than one brain region using rTMS, if previous research has found more than one brain region to be impaired in AN (Davidovic et al., 2018).

Nonetheless, instead of focusing solely on reducing abnormal eating behaviours and depressive symptoms in AN, it may also be useful to target other brain regions with a multitude of functions such as the Insula Cortex. The Insula Cortex is involved in gustatory managing, eating behaviours and interoceptive stimuli processing (Knyahnytska et al., 2019). In the study by Knyahnystka et al. (2019), deep brain stimulation, an advanced and safe form of brain stimulation was used to target the Insula Cortex in patients with AN. It was revealed that post-treatment, patients with AN demonstrated reduced AN obsessions and compulsions, and depression and anxiety scores. This study offers a foundation for the beneficial impacts targeting the Insula Cortex has on improving AN, as this region is involved in multiple symptoms of AN. Also, this study offers support for the suggestion that future brain stimulation interventions should be used to target this brain region. However, due to small numbers of patients in the study and limited research, more studies are required to offer support for the positive effects of this technique and the targeting of this specific region for improving AN symptomatology.

Nevertheless, existing treatments have demonstrated limited effectiveness, with only approximately 50% of patients receiving treatment in clinical trials presenting full recovery post treatment (Hay et al., 2015; Keski-Rahkonen et al., 2009), with some demonstrating negative changes post-treatment (Steinhausen, 2009). One possible explanation is consequent to the lack of available studies assessing AN across the lifespan, which is key information for the development of an effective treatment intervention such as causation, remission, and treatment engagement (Ward et al., 2019). Due to the lack of effectiveness of available interventions, high relapse rates occur due to the lack of patient engagement and high drop off rates during the treatment phase (Cuzzolaro & Fassino, 2018; DeJong et al., 2012; Grilo et al., 2012). As a consequence of this, additional research is required to better understand the aetiology and origin of eating disorders and what causes the maintenance of these disorders. In better understanding this, more effective treatment interventions can be developed to target these factors, which will help reduce relapse rates and mortality rates surrounding these conditions. In order to achieve this, more approaches in understanding bodily processing in eating disorders will provide a richer understanding (Cuzzolaro & Fassino, 2018).

1.3.5 Anorexia and Interoception

Another main characteristic of this eating disorder is that individuals with AN show alteration in interoceptive processing. There are various facets of interoception, which includes interoceptive accuracy, which is the capacity in perceiving physiological sensations, interoceptive sensibility, which involves judgements of one's internal capability to identify bodily sensations, and interoceptive awareness, referring to an individual's metacognitive awareness of one's interoceptive accuracy (Garfinkel & Critchley, 2013). Interoceptive awareness, examined through various measures such as EDI-3, multidimensional assessment of interoceptive awareness questionnaire (MAIA) and The Body Awareness Questionnaire, is a contributor towards an individual with AN's abnormal interpretation of the internal physiological condition of their body (Barca & Pezzulo, 2018; Berner et al., 2018; Fassino et al., 2004; Jenkinson et al., 2018; Kaye et al., 2009; Khalsa et al., 2015; Martin et al., 2019; Matsumoto et al., 2006; Merwin et al., 2010; Pollatos et al., 2008). This is core to the emergence and maintenance of this eating pathology (Jacquemot & Park, 2020; Kaye et al., 2009; Strigo et al., 2013). Individuals with AN have reduced awareness in sensations such as taste, hunger, stomach distention, pain, heartbeat, and gut attention (Kerr et al., 2016; Monteleone & Maj, 2013; Oberndorfer et al., 2013; Perez, Coley, Crandall, Di Lorenzo, & Bravender, 2013; Pollatos et al., 2008; Strigo et al., 2013). Interoceptive awareness deficits have also been associated with body dysmorphia, which is believed to contribute towards the maintenance of negative eating behaviours in this eating pathology (Jacquemot & Park, 2020). Although a plethora of investigations have offered support for interoceptive deficits in AN, a study conducted by Eshkevari et al. (2014) revealed no differences between healthy control and AN patients in the heartbeat detection task. However, although the case, the use of this measure to determine interoceptive inaccuracy has been debated (Eshkevari et al., 2014) and interoception as a whole is a concept not fully understood in psychiatry (Khoury et al., 2018). It has been suggested that both interoception and body image concerns are connected, as interoception involves the physiological condition of the body and body image involves the perception, feelings, and attitudes one has about their body, both of which are crucial components of our sense of self and identity. Therefore, in AN, greater interoceptive deficits are linked with body image concerns and misperceptions (Badoud & Tsakiris, 2017; Berner et al., 2018; Gaudio et al., 2014).

Nevertheless, although the symptoms of AN are clear, the aetiology surrounding this condition remains unknown and requires further investigation. A potential suggestion for the aetiology for AN as revealed in prior neuroimaging studies, is a dysfunction in the dopamine-based reward system of the Basal Ganglia (Avena & Bocarsly, 2012; Kaye et al., 2013). This system is important in driving food approach by sending signals to higher order brain regions which compare the current and future experience of food with past experience of food and constantly update this prediction. In AN, this updated information will be impacted by prediction errors and the assumption of a current and future negative experience of food (Frank, 2013). It is unclear whether these abnormalities are the cause or the result of chronic dysfunctions in eating behaviour. Another proposal is that the restricting food intake and extreme exercising have become abnormally rewarding for people with AN, similar to the rewarding value of an addiction (Scheurink et al., 2010). Some researchers have suggested both a reduced experience of pleasure associated with food (food anhedonia) which is associated with a hyporesponsive striatal dopamine system (Zink & Weinberger, 2010).

1.3.6 Anorexia and social cognitive ability

Furthermore, another key feature which is suggested to be impaired in AN, which could explain the maintenance of this disorder, is the lack of social cognitive ability, including an emotion recognition deficit (Caglar-Nazali et al., 2014). People with AN have been found to show attentional biases when processing human emotion, focusing more on angry or negative facial expressions (Cardi et al., 2017; Harrison et al., 2010). This has been linked to previous adverse social experiences (Cardi et al., 2017) or lack of pleasant feelings from social interactions (social anhedonia) (Tchanturia et al., 2013). It has been suggested that an impaired social cognition could play a large role in the maintenance and onset of this disorder (Arcelus et al., 2013; Castro et al., 2010; Zucker et al., 2007). Individuals with AN are typically reserved, have limited social networks, and self-report poorer quality and quantity of relationships (Tchanturia et al., 2013; Tiller et al., 1997). In addition to impaired emotion recognition deficits, research has also suggested that people with AN display cognitive and affective theory of mind (ToM) alterations (Gál et al., 2011; Hamatani et al., 2016; Russell et al., 2009; Tchanturia et al., 2018; Zucker et al., 2007). ToM is the ability to attribute mental states (intentions, feelings, beliefs) to others and explain and predict others' behaviour, which involves the decoding of affective stimuli (Bora & Köse, 2016). One important aspect of ToM is cognitive perspective-taking which is one's capacity to compare state of self (1st person perspective) with another individual (3rd person perspective) using visual, perceptual, and conceptual domains of oneself (Ruby & Decety, 2003). Both these perspectives involve different processes of cognitive ability, with 3rd person perspectives associated with cognitive empathy which is the understanding of another individual's mental state. First person perspective is taking more of an embodiment of the action being observed, to understand how the action would feel to oneself (Aichhorn et al., 2006; Cooper & Mohr, 2012; Haggarty, 2018; Ruby & Decety, 2003). As a result, specific brain regions are activated i.e., as outlined in Otsuka et al. (2011), the caudate nucleus is slightly more activated during the 1st person perspective condition, whilst the left dorsolateral prefrontal cortex (DLPFC) is more activated in the 3rd person perspective condition. Not only are these regions involved in the process, Frith and Frith (2003) have revealed that ToM involves an array of brain regions such as the medial prefrontal cortex, temporal pole, anterior cingulate cortex and the anterior and posterior superior temporal sulcus, the temporo-parietal junction and inferior frontal gyrus (Frith, 2006; Saxe et al., 2004)

There has been emerging evidence that ToM perspective taking is impaired in individuals with AN (de Sampaio et al., 2013). In the study of de Sampaio et al. (2013), two tasks were used to assess ToM performances on individuals with AN, BN, and healthy controls. One of these comprised of the Reading the Mind in the Eyes (RME) task. This is a task which measured affective ToM and involved presenting participants with 36 images of the area of eyes of individuals depicting different mental states. Participants have to select out of four options, the word that best describes what that individual is feeling. A second, the Faux Pas Test (FPT) task, assessed cognitive and affective ToM, involving scenarios where a faux pas is made i.e., someone has mistakenly said something they should not have in a social situation. Patients are asked questions to apprehend whether or not they recognised that a faux pas was made. It was revealed that people with AN performed significantly worse than individuals with Bulimia and healthy controls on the RME task and low performances were also observed in the FPT. Thus, this study offers support for an impaired affective ToM in AN and that this impairment is more prevalent compared to individuals with Bulimia Nervosa. Similar results regarding an impaired ToM measured through the RME, have also been previously reported (Russell et al., 2009; Harrison et al., 2010; Oldershaw et al., 2010; de Sampaio et al., 2013).

Furthermore, fMRI studies have revealed that even after recovery, individuals with AN have reduced functioning in the social cognitive network, compared to healthy controls, which can account for their difficulty in ToM both 1st and 3rd perspective taking (Bora & Köse, 2016; McAdams & Krawczyk, 2011). Nevertheless, conflicting results regarding people with AN having an impaired ToM have been reported (de Sampaio et al., 2013; Medina-Pradas et al., 2012) and thus requires more attention and investigation.

1.3.7 Evidence for atypical discriminatory touch responses in Anorexia Nervosa

Body image disturbances in AN is present at both a cognitive affective level i.e., relating to body dissatisfaction and also perceptually which can be measured through tactile localisation (Gadsby, 2017). Tactile perception is important as accurately localising tactile stimuli i.e., sense of touch on the skin, provides information regarding body size and mental representations of body size in a given space (Serino & Haggard, 2012). Nonetheless, recent evidence has suggested that individuals with AN demonstrate somatosensory impairments of body representations and tactile disturbances (Spitoni et al., 2015). In Spitoni et al. (2015) study, when people with AN were asked to make judgement of the distance between two tactile stimuli at different body regions, they typically overestimated the distance between these points. Similar results were also observed in Keizer et al. (2011) whereby both individuals with AN and HCs were recruited in order to examine tactile perception and the association with visual body image and body dissatisfaction. It was revealed that AN patients displayed tactile disturbances and had body image misperceptions and dissatisfaction. The higher the body dissatisfaction reported, the greater the overestimation of tactile perception and misperception in body image. A further study conducted by Keizer et al. (2012) discovered that like found previously, AN patients displayed overestimations in their tactile perception and disturbances in the mental representation of their body image in particular relating to the abdomen. Furthermore, they also differed in their somatosensory perception i.e., the detection of pressure to different body regions. Furthermore, a more recent study conducted by Engel et al. (2022) who focused on both people with AN and RAN investigated tactile perception of the abdomen and arm directly after stimulus presentation or with a 5 second delay. It was revealed that both individuals with AN and RAN had greater overestimations in tactile perception when a delay was present, with AN patients displaying greater uncertainty in their responses. Overall, all studies offer support for an impaired body representation in AN and imply that body size estimates negatively impact the processing of tactile stimuli applied to the skin (Spitoni et al., 2015). In addition, that tactile disturbances manifest even when in recovery from AN (Engel et al., 2022).

1.3.8 Evidence for atypical responses to affective touch system in Anorexia Nervosa

Recent research has provided evidence for impairment in the affective touch system in individuals with eating disorders, specifically AN, which could account for their impaired social cognitive ability (Bischoff-Grethe et al., 2018, 2020; Crucianelli et al., 2016, 2021; Davidovic et al., 2018). These investigations have found reduced pleasantness ratings in the receiving of actual and prediction of pleasant touch in this clinical population (Bischoff-Grethe et al. 2018; Crucianelli et al., 2021). For example, Crucianelli et al. (2016) applied actual CT-optimal (3 cm/s) and non-optimal (18 cm/s) velocities to the forearm of people with AN and healthy controls. It was revealed that AN, compared to healthy controls, rated pleasantness of CT-optimal touch as less pleasant. In further support, Davidovic et al. (2018) used functional magnetic resonance imaging (fMRI) to assess brain impairments in AN when experiencing actual affective touch and were asked to rate the pleasantness of skin stroking. Compared with healthy controls, people with AN rated skin stroking across the dorsal forearm as significantly less pleasant (Davidovic et al., 2018). Similarly, this was also observed in Bischoff-Grethe et al. (2018) who investigated neural responses to actual affective touch on patients with remitted AN. These patients also reported higher intensity ratings of touch (Bischoff-Grethe et al., 2018). Conflicting evidence was observed in Crucianelli et al. (2021) in that abnormal responses of touch were not observed when participants received actual touch, but rather abnormal responses occurred in the anticipation of vicarious imagined touch. More recently, Tagini et al. (2023) investigated pleasantness responses to both vicarious imagined touch which involved both individuals with AN and healthy controls visualising touch being received to their left forearm and also experience actual real touch delivered using a brush tool and the experimenter's hand. Levels of social anhedonia and experiences of touch across participants lifespan was also measured. It was revealed that although people with AN displayed lower experiences of touch across the lifespan and higher social anhedonia than HCs, there was no observed differences in pleasantness ratings for both imagined and directly felt touch.

Together, these studies provide a basis for an aberrant CT-touch system in AN, due to abnormal responses observed when these patients rated the pleasantness of affective touch. Moreover, this impairment could be possibly linked to their lack of interoceptive awareness and distorted body image perceptions (Crucianelli et al., 2016), as not only is the hedonic processing of affective touch impaired, but also the perceptive processing. Thus, these studies offer justification for the need to target hedonic and perceptual impairments of affective touch in AN, as this impairment still manifests in these patients after recovery and could be a cause of recurring remission rates for these patients.

Overall, disruption in the processing of affective touch has been regarded as a possible explanation for the aetiology and maintenance of symptoms of AN, such as body image distortions (Crucianelli et al., 2021). Also, interoception is believed to play an important role in healthy body representation and bodily awareness (Gentsch et al., 2016). Therefore, body image distortions and lack of self-awareness displayed in AN patients, could be linked to the mismatch between actual and anticipated interoceptive perceptions, as well as impairments in the perception and encoding of the rewarding value of receiving affective touch to different body regions (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016; Perez et al., 2013). Yet, most of the research examining the link between interoceptive deficits and AN have mainly concentrated on unrewarding interoceptive signalling i.e. pain (thermal), neutral interoceptive signalling i.e. heart rate, and interoceptive signalling specific to the symptoms of AN such as hunger and taste (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016), rather than rewarding interoceptive touch such as affective touch processing, which could account for the lack of understanding surrounding the origin of this disorder. Furthermore, only a few investigations have focused on atypical responses to affective touch in AN, therefore more studies are required in order to offer further support for atypical responses in AN such as a reduction in touch pleasantness and higher intensity ratings, when these individuals receive this type of touch. In addition, that abnormal processing of affective touch is linked to an impaired Insula Cortex functioning and potentially also linked to reduced activation of the mPFC.

1.3.9 Impaired affective touch brain regions in Anorexia Nervosa

1.3.9.1 Directly felt touch regions in AN

Prior investigations have linked an impaired bodily interoceptive awareness in AN (Davidovic et al., 2018; Kaye et al., 2009; Pollatos et al., 2008) to a dysfunction in the Insula Cortex, which is the recipient to CTs, who respond to affective touch and the region responsible for interoceptive processes (Berner et al., 2018; Kerr et al., 2015; 2016; Kim et al., 2012; Strigo et al., 2013; Wagner et al., 2008). In addition, this impaired Insula Cortex functioning is believed to continue after recovery from AN with women still demonstrating interoceptive impairments and hypoactivation of the Anterior Insula to rewarding and pleasurable tasting foods (Oberndorfer et al., 2013). Due to disruptions in the Insula Cortex, people with AN may not be able to integrate emotional information with sensory experience (Nunn et al., 2008) and as such, this population suffers from a distorted sense of self both physiologically and perceptually (Pollatos et al., 2008; Kaye et al., 2009). It is this lack of interoceptive awareness that is associated with body image concerns and disturbances in AN (Badoud & Tsakiris, 2017). It is, therefore, important to investigate the CT-touch system in AN in order to better understand social difficulties associated with this disorder, as affective touch is an interoceptive modality and also the CT-touch system is specialised for detecting varying velocities of touch applied to the skin (Olausson et al., 2008). In addition, as well as the Insula Cortex, it has been previously revealed that other regions involved in social perception and social cognition are also impaired in affective touch processing in AN. One of these regions includes the frontal pole (Davidovic et al., 2018), which comprises of the medial and lateral area, specifically known as the vmPFC (Koechlin, 2011). Overall, these investigations offer support for an association between the Insula Cortex and a link with the vmPFC in reduced pleasantness of interoceptive stimuli. Thus, a dysfunction in both these regions could account for body image disturbances in AN (Davidovic et al., 2018)**.** However, a more recent study by conducted Frost-Karlsson et al. (2022) investigated through participants with AN and healthy controls, functional brain imaging whilst participants stroked their own arm (self-touch task) and were stroked by an experimenter (other-touch task). It was revealed that the AN group displayed comparable responses to HCs in the processing of both self-touch and other-touch in which regions such as S1, pSTS, frontal regions, temporal regions and the motor cortex displayed increased activity in response to both types of touch. Therefore, this study suggests that individuals with AN have an intact tactile self-other distinction (Frost-Karlsson et al., 2022). Nevertheless, due to the limited research surrounding affective touch in AN, more neuroimaging investigations are required in order to offer more support for an impaired Insula Cortex functioning and also to understand if the vmPFC plays a role in the social perception of touch applied to different body regions. Furthermore, to investigate whether individuals with AN have an intact tactile self-other distinction and whether atypical responses to affective touch may occur due to the anticipation of the touch as opposed to the actual touch received (Frost-Karlsson et al., 2022).

1.3.9.2 Vicarious touch regions in AN

In relation to the vicarious observation of affective touch, research has suggested that viewing others receiving touch induces touch experiences in the observer, not only activates the Insula Cortex, a region involved in receiving touch, but also regions such as the Somatosensory Cortex involved in self-processing (Björnsdotter et al., 2014; Ebisch et al., 2011; Gazzola et al., 2012; Gordon et al., 2013; Masson et al., 2018; McCabe et al., 2008; McGlone et al., 2014; Miguel et al., 2019; Morrison, 2016; Olausson et al., 2002, 2008). Given that previous studies have found reduced pleasantness in individuals with AN (Crucianelli et al., 2016, 2021; Davidovic et al., 2018), and that observing touch activates touch experiences and corresponding brain regions such as the Insula Cortex and Somatosensory Cortex (Masson et al., 2017, 2018), it is anticipated that when people with AN are asked to rate the perceived pleasantness of others receiving affective touch, they will use their own experiences to interpret the feelings generated in another, which could account for an impaired ToM in individuals with AN (Gál et al., 2011; Hamatani et al., 2016; Russell et al., 2009; Tchanturia et al., 2018; Zucker et al., 2007).

Overall, the nature of this eating pathology is poorly understood due to the complexity of the disorder, therefore requiring further investigation (Clarke et al., 2012). One explanation is due to the limited capacity fMRI studies can provide regarding visual perception and touch (Favaro et al., 2012). Therefore, this study provides strong justification for the need for more methods such as neurophysiological techniques, which have the ability to assess these aspects of AN without any constraints. In better understanding the aetiology of this condition and the brain regions impaired, more successful treatments for this disorder can be developed.

Chapter 2

Methods for studying responses to affective touch in AN and measures to assess AN symptom severity

2.1 Affective Touch Measures

One of the main methods for assessing affective touch responses is through the direct experience of gentle touch applied to the skin using a soft brush, with touch delivered at CT-optimal (i.e., 1-10 cm/s) and CT non-optimal velocities (i.e., < 1 cm/s or > 10 cm/s). Participants are then asked to evaluate the pleasantness of that touch using a 100-point VAS (Ackerley et al., 2014; Croy et al., 2016; Essick et al., 1999; Löken et al., 2009, 2011; Olausson et al., 2008; Olausson et al., 2010; Wijaya et al., 2020). This has largely been utilised in combination with fMRI to assess the brain regions involved during the processing of affective touch (Björnsdotter et al., 2014; Gordon et al., 2013; Morrison, 2016; Perini et al., 2015). On the other hand, other experimental methods incorporate microneurography, which measures single-unit impulses from peripheral nerves whilst a participant is receiving and evaluating gentle stroking to their skin (Wessberg et al., 2003). Furthermore, other studies have assessed unconscious facial muscle activity through facial electromyography (EMG) in responses to videos of affective touch (Ree et al., 2019).

As well as direct experience of affective touch, observed affective touch can be measured using videos clips depicting one actor delivering touch and one actor receiving touch to different body regions at different velocities. These videos are displayed to participants depicting only the hand of the actor delivering touch and the region of the body of the touch receiver (Trotter et al., 2018; Walker et al., 2017). After viewing each video, participants are asked to make a judgement of how pleasant they believe the touch would be for themselves. This method was utilised in studies 1 (Chapter 3), 2 (Chapter 4), and 4 (Chapter 6) and also included an additional measure of other-directed touch, in which participants evaluated how pleasant they think the touch is for the actor receiving the touch. These observed affective touch videos were used to assess vicarious affective touch responses in individuals with high and low EDs risk (Chapter 3) and also with people with AN, RAN and HCs (Chapter 4).

Another dimension of affective touch is imagined social touch (Lucas et al., 2015). This can be measured in combination with direct experience of affective touch and fMRI to understand if the regions involved in actual touch, are also involved in imagined touch (Lucas et al., 2015). For study 3, imagined social touch was measured using ‘the Virtual Touch Toolkit’ (Najm et al., 2022), a virtual mobile phone application, which was used to assess soothing/ unpleasantness of imagined social touch to various body regions, delivered from a loved one compared to an acquaintance, in individuals with high and low body image disturbances.

2.1.1 Observed affective touch videos (Studies 1, 2 and 4, Chapters 3, 4 and 6)

The observed affective touch videos consisted of 6-seconds video clips, which depicted a male actor delivering touch to a female actor, across various body locations. For consistency, we kept males as the touch deliverer and females as the touch receiver. As well as consistency, prior research has revealed that theory of mind is more accurate when the individual they are taking the perspective of is also of the same sex i.e., female for the current PhD project (Wacker et al., 2017). These videos only displayed males providing the touch, as compared to females, males instigate touch more frequently (Henley, 1973; Stier & Hall, 1984). To avoid any confound linked to emotional expression of the agent delivering the touch (Harjunen et al., 2017), all videos only displayed the body site of the receiver and the hand of the touch deliverer. This was to ensure that the actors’ faces were not included in the video. As found previously, it is important not to include emotional expressions, as Ellingsen et al. (2014) revealed that factors such as facial expressions affect perceived pleasantness of touch. These researchers discovered that smiling faces increased pleasantness ratings of touch, whereas faces presenting a frowning expression, decreased pleasantness ratings of touch.

Furthermore, all videos were selected from a database of video clips previously used by our lab group (Trotter et al., 2018a). Touch was delivered across five different body regions: a glabrous skin site with sparse CT innervation such as the palm vs. CT-innervated hairy skin sites, such as the back, ventral forearm, cheek, and upper arm, (Watkins et al., 2020), with 3 different stroking velocities: two of which were not optimal for CT activation (static (0 cm/s) and 30 cm/s touch) and one which was optimal for CT activation (5 cm/s). The videos presented were randomised and counterbalanced amongst participants using a randomisation generator on both Qualtrics (Version 60939 of the Qualtrics Research Suite. (Copyright © 2015 Qualtrics., Provo, UT, USA. http://www.qualtrics.com) and E-Prime 3.0 (Psychology Software Tools, Pittsburgh, PA).

Immediately after viewing each observed affective touch video, participants were probed to respond to two questions, one asking: "How pleasant do you think that action was for the person being touched?" (Question 1: other-directed touch) using a 100-point VAS ranging from 0 = very unpleasant to 100 = extremely pleasant (Trotter et al., 2018a). This question concerns the ability of participants to determine mental states of another and evaluate how pleasant the touch received was for the actor in the video. Participants also responded to a second question asking: "How much would you like to be touched like that?" (Question 2: self-directed touch) using a VAS ranging from 0 = not at all to 100 = extremely. This question was more related to the participant themselves in their level of wanting the touch they are viewing (See Figure 2.1.1.2 and 2.1.1.3 for the rating scale used for each question). The order in which these questions were displayed after each video was randomised. All questions and scales were kept consistent for studies 1, 2 and 4 (Chapters 3, 4 and 6).

Overall, a total of 15 videos were selected. Each of the videos were displayed in 240 p YouTube quality in full HD (1920×1080 pixels) at 25 fps rate (Trotter et al., 2018a) (See Figure 2.1.1.1 for visualisation). These videos have been previously validated by Trotter et al. (2018a) and this thesis is the first to use these videos with clinical and subclinical eating disorder populations.

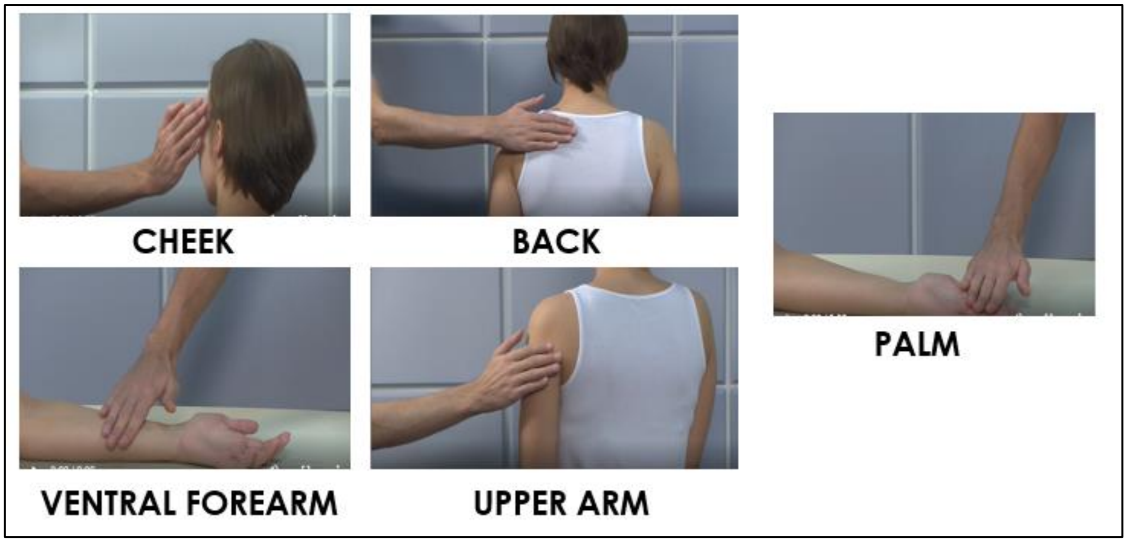

Figure 2.1.1.1 *Visual illustration of the 5 body sites (CT-innervated body regions: Ventral Forearm, Upper Arm, Cheek and Back vs. the non-CT innervated palm) from the affective touch videos used in studies 1 and 2.*

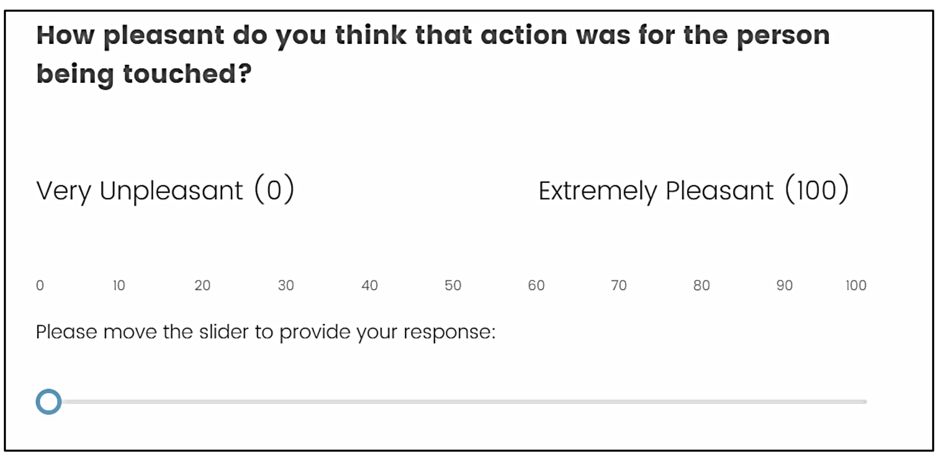

Figure 2.1.2.1. *Visual representation of the scale used for Q1. for the affective touch videos. Participants responded by moving the cursor at the bottom from 0 "Very Unpleasant" to where they felt was appropriate, with a maximum rating of 100 "Extremely Pleasant".*

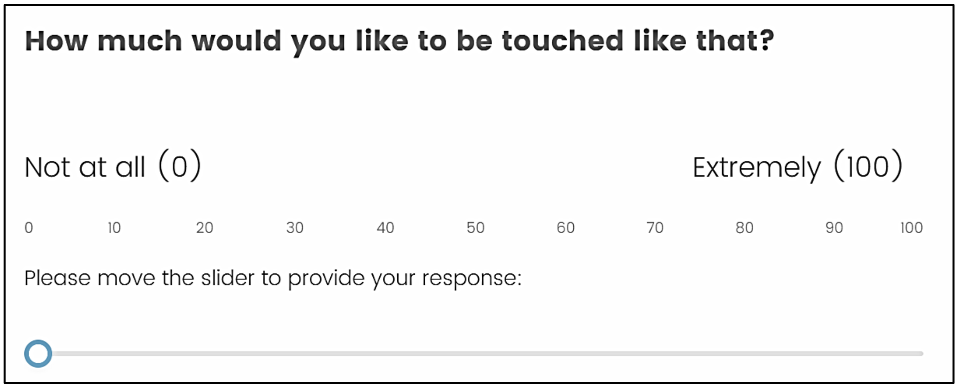

Figure 2.1.2.2. *Visual representation of the scale used for Q2. for the affective touch videos. Participants responded by moving the cursor at the bottom from 0 "Not at all" to where they felt was appropriate, with a maximum rating of 100 "Extremely".*

In studies 1 (Chapter 3) and 2 (Chapter 4), all videos were displayed to participants only once, in a randomised order.

In study 4 (Chapter 6), participants completed the observed affective touch task in which each of the videos was presented 3 times in a completely randomised order, after TMS stimulation was completed. Participants received offline TMS with a theta-burst protocol which lasted 40 seconds (200 bursts, each comprising three pulses at 50% power, 30 Hz frequency, 6Hz burst frequency repeated every 200 ms (5 Hz), 600 pulses in total) as outlined in Goldsworthy et al. (2012) to each of the 3 brain regions (mPFC, S1 and Vertex), depending on counterbalancing (information concerning the TMS protocol, see section 6.5 below) prior to completing the task.

2.2 Social Touch measures

2.2.1 Hands-On application (Study 3, Chapter 5)

The Hands-On application is a newly developed smartphone application, currently in the Beta testing phase. This application allows participants to download and interact with various exercises on their mobile device (Najm et al., 2022), and has been developed with the potential to be used as a research tool to virtually investigate social touch behaviour. The application comprises of various touch exercises, which are categorised into four main types: Mindfulness, Stress Control, Bodily Awareness and Touch Training. The exercises include an array of interactional interfaces such as sound, 3D Models, and text-based instructions. The data collected from this application includes a participant's current emotional state, the performance from the exercise and the emotional state post completion of the exercise.

In study 3 (Chapter 5), participants were provided with detailed instructions on how to download the application and how to navigate to the desired components of the application. This application was available to be downloaded to participants phones (both Android and Apple) to allow participants to interact remotely.

Participants could select the gender, age, and either a male or female avatar that best represents the gender they identified with. Using this 3D virtual avatar/body outline created, participants were asked to use a colour scale from blue soothing (+100) to red unpleasant (-100), using a brush tool, to indicate pleasantness of touch to body sites delivered from a loved one compared to an acquaintance. Heatmaps for both conditions were created separately. Brush type and size could be manipulated by participants to ensure they are as precise as possible and to ensure participants did not colour body parts unintentionally. Each condition for who they are touched by (loved one vs. acquaintance) contained a separate avatar whereby participants coloured all body parts relating to how soothing and unpleasant they find touch to these body sites by these individuals (See Figure 2.2.1.1).

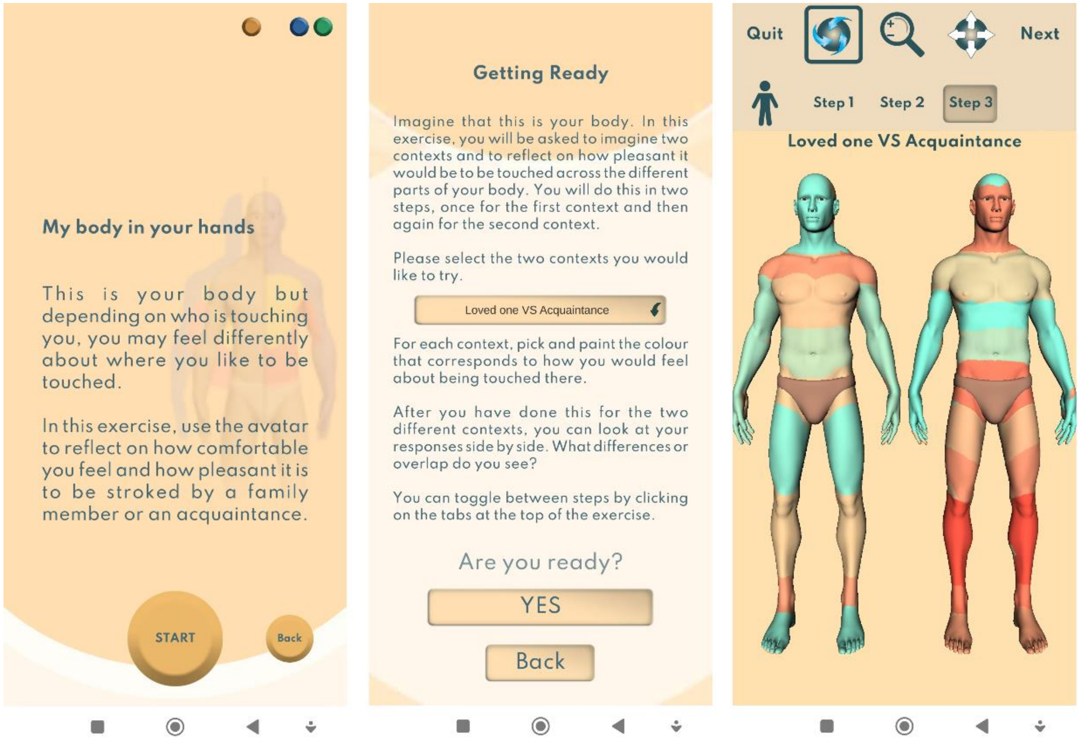

Figure 2.2.1.1. *Image taken of avatars that will be used to determine pleasantness of touch for specific body areas, for both loved one vs stranger touch. Image credit: Prof Merle Fairhurst, The Virtual Touch Toolkit (https://www.unibw.de/virtualtouch-en/virtual-touch-toolkit).*

2.3 Self-report Measures

2.3.1 Screening Questionnaire (Appendix 1)

For study 2 (Chapter 4), an initial set of seven screening questions were used to determine participants' eligibility. The questionnaire asked participants to answer "true" or "false" to a series of statements. These statements included: "I am 18 years old or over.", "I am female.", "I do not suffer from any form of skin condition.", "I do not suffer from any chronic pain condition.", "I am not pregnant.", "I have normal or corrected to normal vision". A final question asked participants to confirm they had read the participant information sheet and they agreed to take part in the study by clicking an "I agree" option. For the healthy control group only, an additional question ascertained that they did not have a current or previous diagnosis of AN. If a participant answered "false" to any of the statements, or did not agree to take part, an "if then" function was applied, so that ineligible participants were directed to the end of the survey, thanking them for their time in taking part (See appendix 1).

To classify clinical populations into AN and RAN groups, patients were required to answer to the following statements in the Demographics Questionnaire: ‘Please specify your current diagnosis of Anorexia Nervosa’ with the options of identifying either: ‘Current diagnosis of Anorexia Nervosa’, ‘Previous diagnosis of Anorexia Nervosa’ or ‘No diagnosis/history of Anorexia Nervosa’. For AN, this group was asked to specify how many years they have had a formal diagnosis, and to declare any treatment they are currently undergoing, through answering the following questions: ‘If you have a current diagnosis of Anorexia Nervosa, for how many years have you had this?’ and ‘Are you currently undergoing any treatment for Anorexia Nervosa (e.g., psychiatric treatments, SSRIs, tranquilizers, and or CBT)?’. The RAN group were asked to identify the number of years they have been recovered from AN: ‘If you have a previous diagnosis of Anorexia Nervosa, for how many years have you been recovered?’. Questions specific to both AN populations were not displayed to individuals with no AN diagnosis (See appendix 2)

For studies 1 (Chapter 3) and 4 (Chapter 6), a set of 8 screening questions was used to determine participants’ eligibility to take part. This Questionnaire asked participants to answer “True” or “False” to a series of statements. These statements include “I am Female” and “I confirm that I have not got a current or previous diagnosis of an eating disorder”. A final question asked participants if they have read the information sheet provided and if they agree to take part in the study by clicking on the “I agree” option if they do. If a participant answered “false” to any of these statements, or did not agree to take part, the researcher contacted them, by the email address provided to let them know that they were unable to take part. These participants were provided with the debrief sheet so they could understand what the study was about (See Appendix 1).

2.3.2 Demographics Questionnaire (Administered in all studies, amended for each investigation’s requirements) (Appendix 2)

The demographic questionnaire requires information concerning participants’ age, gender, and biological sex for all studies. This questionnaire was amended for each study depending on the demographic information required. Ethnicity, relationship status and education level were collected for studies 1 (Chapter 3), 2 (Chapter 4), and 4 (Chapter 6). Participants were also asked to self-report their height (cm/ft) and weight (Kg/lbs) for study 1 and 2, which was used to calculate their Body Mass Index (BMI). For study 4 (Chapter 6), height was collected using a stadiometer and weight was collected using a calibrated bioimpedance digital scale (OMRON BF511), to calculate BMI (See appendix 2).

2.3.3 Multidimensional Assessment of Interoceptive Awareness (MAIA) Questionnaire (Administered in all studies, Chapters 3-6) (Appendix 3)

The Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) is a 32-item questionnaire which was administered to investigate eight dimensions of interoceptive bodily awareness: Noticing (4 items), Not Distracting (3 items), Not Worrying (3 items), Attention Regulation (7 items), Emotional Awareness (5 items), Self-regulation (4 items), Body Listening (3 items) and Trusting (3 items). Four of the subscales identified were found to be strongly associated with eating disorder symptomatology, these included: Not Distracting, Self-regulation, Body Listening and Trusting. All questionnaire items were answered using a 6-point Likert scale ranging from 0 = Never to 5 = Always. Questions included: “When I am tense I notice where the tension is located in my body.” and “I notice when I am uncomfortable in my body”. Each individual dimension is scored by the average of scores from questions corresponding to that subscale, with some questions being reversed scored. This questionnaire is a reliable measure, as it has been previously used in research measuring interoceptive awareness in both healthy populations (Mehling et al., 2012) and with an eating disorder population (Brown et al., 2017). The MAIA questionnaire has good internal consistency, with Cronbach $\alpha = .90$ (Valenzuela-Moguillansky et al., 2015). This questionnaire was selected as it is a good measure for assessing interoceptive awareness in individuals with high and low EDs risk (See appendix 3)

2.3.4 Eating Disorder Examination Questionnaire (EDE-Q) (Administered in study 1, Chapter 3 and study 2, Chapter 4) (Appendix 4)

The Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994) consists of 28 items, which asked participants to self-report any eating disorder symptoms they may have experienced over the last 4 weeks. This questionnaire is comprised of four subscales: Restraint, Eating Concern, Weight Concern and Shape Concern. Questions from this questionnaire included: “How dissatisfied have you been with your shape?” and “Have you had a definite desire to have a totally flat stomach?”. This questionnaire has good internal consistency in clinical populations, with Cronbach $\alpha = 0.70–0.83$ and in healthy populations with Cronbach $\alpha = 0.78–0.93$ (Luce & Crowther, 1999'; Peterson et al., 2007). Individual subscales have also been shown to have good internal consistency: Restraint (Cronbach $\alpha = 0.70–0.85$), Eating Concern (Cronbach $\alpha = 0.73–0.86$), Shape Concern (Cronbach $\alpha = 0.83–0.93$), and Weight Concern (Cronbach $\alpha = 0.72–0.89$) (Berg et al., 2012). In this PhD project, this questionnaire was used to identify the clinical and the healthy control populations, with no AN risk (Garner et al., 1983). A cut off total score of 4 or more is typically used to classify individuals in the clinical range (Carter, Stewart, & Fairburn, 2001; Mond, Hay, Rodgers, & Owen, 2006). A sum of scores from all four subscales gave an indication of the severity of eating disorder symptoms for both studies 1 and 2 (See appendix 4).

2.3.5 Eating Disorder Inventory-3 Questionnaire (EDI-3) (Administered in studies 3 and 4, Chapters 5-6) (Appendix 5)

The Eating Disorder Inventory-3 (EDI-3) (Garner, 2004) is a 91 item self-report questionnaire assessing eating disorder symptomatology. This questionnaire assesses 12 subscales, 3 of which are core for assessing eating disorder symptomatology: Drive for Thinness, Bulimia and Body Dissatisfaction, which collectively examines eating disorder risk by summing these subscale scores (risk composite score). The other 9 subscales investigate personality traits generally associated with eating disorders: Low Self-esteem, Personal Alienation, Interpersonal Insecurity, Interpersonal Alienation, Interoceptive Deficit, Emotional Dysregulation, Perfectionism, Ascetism and Maturity Fear. In this thesis, we focused on the ED risk composite score, to assign participants into high and low EDs risk. We also used interoceptive deficit as a subscale for correlations. Questions are answered using a 6-point Likert scale ranging from 0 = “never” to 5 = “always”.

Questions from this questionnaire include: “I eat when I’m upset” and “I think about dieting”. This questionnaire has been previously validated with clinical and non-clinical samples across various cultures (Clausen et al., 2011). This questionnaire was therefore suitable to be used with subclinical populations. This questionnaire was emailed before study commencement to assess participants’ risk of EDs (high vs. low EDs risk). Participants were recruited for study 3 (Chapter 5) on the basis of their Eating Disorder Risk Composite (EDRC) score. For this study, the median split was used to assign participants into high levels of BIDs and low levels of BIDs. For study 4 (Chapter 6), participants were not pre-selected based on this score. Instead, this questionnaire was used to assess whether inhibition of vmPFC and S1 was causative of a reduction in pleasantness ratings and whether this was associated with ED symptomatology. The EDI-3 has good internal consistency for each subscale (ranging from $\alpha = .75$ to $\alpha = .92$) and discriminative validity (Clausen et al., 2011) (See appendix 5).

2.3.6 Dysmorphic Concern Questionnaire (DCQ) (Administered in all studies, Chapters 3-6) (Appendix 6)

The DCQ (Oosthuizen et al.,1998) is a short, 7-item questionnaire and is a reliable tool which is used to assess both behavioural and cognitive aspects of dysmorphic concerns, as well as risk of body dysmorphic disorder (BDD). Participants are asked to rate each item on a 5-point Likert scale ranging from 0 = “not at all” to 4 = “much more than most people.” All 7 items were totalled for each participant, to give an overall score for dysmorphic concern. These scores range from 0-28, with a score of 9 or more indicative of high dysmorphic concern (Mancuso et al., 2010). This questionnaire has good internal consistency $\alpha = .80$ (Jorgensen et al., 2001). The DCQ is a questionnaire which can also be administered to subclinical populations, those high and low EDs risk for study 1 (Chapter 3) and high and low levels of BIDs for study 3 (Chapter 5), making this a suitable questionnaire to be used with the populations tested (See appendix 6).

2.3.7 Touch Experiences and Attitudes Questionnaire (Administered in all studies, Chapters 3-6) (Appendix 7)

The Touch Experiences and Attitudes Questionnaire (TEAQ, Trotter et al., 2018b) is a 57-item questionnaire which examines current experiences of positive touch and positive experience of touch during childhood, as well as an individual's attitudes towards positive touch. Questions were answered using a 5-point Likert scale ranging from 1 = "Disagree strongly" to 5 = "Agree strongly". Questions included: "I dislike people being very physically affectionate towards me." and "There was a lot of physical affection during my childhood." A mean score is calculated for each of the six subscales: friends and family touch (11 items), current intimate touch (14 items), childhood touch (9 items), attitude to self-care (5 items), attitude to intimate touch (13 items) and attitude to unfamiliar touch (5 items), with negatively worded questions reversed scored. The TEAQ questionnaire was found to have good internal consistency with Cronbach α= 0.78–0.92 (Trotter et al., 2018b). This thesis also provides first hand assessment of this questionnaire with high (See study 2, Chapter 4) and low EDs risk populations (See study 1, Chapter 3) (See appendix 7).

2.3.8 COVID-19 touch experiences and eating behaviour Questionnaire (Administered for Study 1, Chapter 3 and study 2, Chapter 4) (Appendix 8)

This non-standardised scale questionnaire consisted of 12 questions and was designed to measure touch experience and eating behaviour during the COVID-19 pandemic. A 100-point VAS was used for participant responses and for each question. Participants optionally provided additional comments concerning their responses. The questionnaire consisted of 6 questions concerning touch experiences, eating behaviour, physical activity rate, social isolation, the current country participants live in, whether their country is currently in lockdown and one for participants to state their level of risk of contracting COVID-19. Questions included: "To what extent has the level of touch you give to people within your household reduced since COVID-19?" and "Since COVID-19, I am feeling a great deal of social isolation from my usual support networks i.e., family and friends" (see appendix 8). This questionnaire was used to investigate whether changes in touch experiences since COVID-19, could account for any unexpected changes in touch pleasantness ratings in studies 1 (Chapter 3) and 2 (Chapter 4) (See Appendix 8).

2.3.9 TMS safety-screening Questionnaire (Administered for Study 4, Chapter 6) (Appendix 9)

Before the experimental session, a 20-item pre-screening questionnaire was administered ensuring suitability for participation (Keel, Smith, & Wassermann, 2001). This questionnaire comprised of yes or no responses and in some instances required additional information on questions. The questionnaire asked participants questions concerning whether they have any neurological disorders, family history of neurological disorders, non-removable metal, for example, metal in the brain and that the participant is not pregnant etc. to ensure participants met the inclusion criteria for the study (See appendix 2). Participants with enhanced risk of the side effects of TMS, based upon answers to these questions, were excluded from the investigation (Rossi, Hallett, Rossini, & Pascual-Leone, 2011) (see appendix 9).

2.4. Exteroceptive Measures

2.4.1 The Tactile Estimation Task (TET) (Study 4, Chapter 6)

Tactile body image was measured using the Tactile Estimation Task (TET), which has been previously used with AN populations (Keizer et al., 2011). The TET involved applying two tactile stimuli simultaneously to participant's right forearm using a Calliper tool. During this task, participants were blindfolded and asked to estimate the distance between the two tactile stimuli using their thumb and index finger, which was then measured by the researcher. The distance between the two tactile stimuli was changed (i.e., 50 mm, 60 mm, and 70 mm) and was applied randomly to the same body region (Keizer et al., 2011).

The mean distance is calculated for each of the 5 trials per distance (50 mm, 60 mm, and 70 mm). After which, a total mean distance is calculated in order to assess over or under estimation of tactile estimation, with the score of 60 mm being the comparison value (middle value). A score significantly above 60 mm is indicative of overestimation of tactile estimation, whilst a score significantly below 60 mm demonstrates underestimation. A score close to 60 mm demonstrates no tactile disturbances i.e., no over or under estimations.

2.5 Psychophysiological Measures

2.5.1 Transcranial Magnetic Stimulation (Study 4, Chapter 6)

2.5.1.1 A brief introduction to Transcranial Magnetic Stimulation

Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation neurophysiological technique, despite fundamentally being established as a diagnostic tool, this technique allows for the investigation of brain functioning (Hallett, 2007; Horvath et al., 2011). This measure can temporarily interfere with the neural functioning in a targeted cortical brain region (Horvath et al., 2011), as this technique can excite or inhibit this region (Hallett, 2007). Typically, TMS is used to assess brain functioning across a range of behavioural performances such as accuracy and signal detection theory etc. utilising TMS methods into research allows experimenters to investigate a hypothesis relating to a causal relationship between cognitive functioning and a specific brain area (Hallett, 2007).

The distinctive benefits of TMS are that an experimenter can investigate a neurotypical individual, without the added difficulties of testing individuals who are not neurotypical and may have co-morbid illnesses. Using neurotypical individuals helps with controlling conditions i.e., ensures no other factors such as brain impairments to non-targeted regions have any influence (Robertson et al., 1999). In addition, using neurotypicals helps to prevent added time to an experiment i.e., fewer participants are required, as these individuals can act as their own control group, in which TMS can be applied over a control region not being investigated such as the Vertex. The Vertex is a region which when targeted does not have any significant influence on brain functioning (Jung et al., 2016). As participants can take part in all conditions, this allows for a within-subjects design to be used, allowing for better control of individual differences and therefore strengthens the validity of findings and enables more solid conclusions to be made (Pitcher, 2009).

2.5.1.2 What is TMS and what are the principles of this neurophysiological technique?

Michael Faraday, who was an English physicist, was the first individual to discover the physical principles of TMS in 1881 (Fitzgerald & Daskalakis, 2013;

Heshmati, 2017; Horvath et al., 2011; Noohi & Amirsalari, 2016). He discovered that a single pulse of electric current moving through a coil of a wire creates a magnetic field. The rate to which this magnetic field changes, is largely dependent on the induction rate of the secondary current passing through the adjacent conductor (Fitzgerald & Daskalakis, 2013; Heshmati, 2017; Horvath et al., 2011; Noohi & Amirsalari, 2016). During a session of TMS, a magnetic coil is placed and held securely over a participant's scalp, which produces an electrical current in the participant's brain, which is consequent to electro-magnetic induction. The current easily passes through the skull and the large levels of electrical current produced in the brain depolarises neurons in the targeted region (Horvath et al., 2011; Pitcher, 2009).

The earliest endeavour to modulate brain activity utilising magnetic fields occurred in the 19th century. This was originally conducted by the French physician Arsene d'Arsonval, but it was too difficult to establish a causal role of TMS in altering brain functioning. Nevertheless, TMS continued to evolve over the years, making it a useful tool in establishing this causative link between brain functioning and behaviour (Horvath et al., 2011). Barker et al. (1985) were the first to successfully inhibit normal cortical functioning, through examining muscle twitches caused from motor evoked potentials in the motor cortex (Baker et al., 1985).

For modern TMS equipment, a large electrical current passes through the coil and generates a magnetic field which is perpendicular to the angle of the orientation of the coil. When localised on the scalp, this magnetic field generated by the coil passes through the skull and an electrical field is induced in the cortical region. This alters the electrical state of the axons in the cortical region and the voltage causes depolarisation of the cell membrane and action potential i.e., triggers some neurons to discharge and for others their resting membrane potential increases (Sack & Linden, 2003). Thus, the magnitude of TMS disruption of neural processing in a specific brain region, is dependent upon the orientation of the coil and nerve fibres (Amassian et al., 1992), as when the TMS coil is tangent to the orientation of the nerve fibre, the post-stimulation effects are at its optimum (Pitcher, 2009).

The magnetic coils which are used to deliver this electrical current, have varying shapes. A single round coil is relatively effective at altering neural processing in a specific brain area (Hallett, 2007), whereas a figure-of-eight coil produces a more focal effect of stimulation and does not impact surrounding brain regions to the one of interest (Hallett, 2007; Pitcher, 2009; Ueno et al., 1988). The current flows through the wings of a figure-of-eight coil in opposing directions and unites in the centre point of the coil. It is at this point that stimulation is given. Importantly, the wings of the figure-of-eight coil are away from the scalp of the participants and do not stimulate brain regions beneath. The effect of stimulation diminishes the further away from the centre point, with the centre point producing the highest magnetic field (Pitcher, 2009).

2.5.1.3 The spatial and temporal resolution of TMS

Although TMS has poorer spatial and temporal resolution compared to other cognitive neuroscience techniques (Bolognini & Ro, 2010), TMS can still be used to investigate the cognitive function of a specific brain region (Slotnick, 2013). The spatial resolution of TMS is approximately 0.5-1 cm and therefore cannot examine the functional processing from small-grained spatial structures of the cerebral cortex (Fusco et al., 2022; Thielscher & Kammer, 2002; Toschi et al., 2008). The spatial resolution is very much reliant upon the shape of the coil used for stimulation, as larger diameter coils can stimulate across larger parts of a region. The diameter of the components of a figure-of-eight coil is 45 mm, due to this, this coil has the capacity to stimulate small sections of the primary motor cortex (Bolognini & Ro, 2010; Ro et al., 1999).

The temporal resolution of TMS is dependent upon the TMS parameters used such as the stimulation time, intensity and coil that is employed (Bolognini & Ro, 2010). If single-pulse TMS is utilised, the temporal resolution is high and can in provide understanding of the functioning of the specific region, due to its ability to disrupt the functioning of the targeted region in milliseconds. If single-pulse stimulation is delivered to the Visual cortex during experimentation, it is possible to inhibit visual perceptual processing, when stimulation is delivered between ~70 and 140 milliseconds post onset to the presentation of a visual stimulus. Due to the transient nature of TMS, an investigator has the flexibility to assess brain functioning of a specific region in different experimental conditions (Amassian et al., 1989; Bolognini & Ro, 2010; Ro et al., 2003).

2.5.1.4 The benefits of TMS for research and therapeutic purposes

Most importantly, TMS is a technique which can be used to assess the function of a specific region in a safe, low cost-efficient method which does not cause any long-lasting side effects (Horvath et al., 2011). Repetitive Transcranial Magnetic Stimulation (rTMS) is a method of TMS which is able to briefly disrupt neuronal processing for a short time beyond the period of stimulation. This disruption to brain activation may show to be valuable in the determination of causal relationships between brain processing and behaviour (Horvath et al., 2011). In addition, due to the moderation in functioning of a specific region lasting longer than the stimulation period, this type of neurophysiological technique has shown to be valuable to the treatment of numerous neurological illnesses, particularly in individuals who are not responding to other forms of treatment (Horvath et al., 2011). TMS has been used previously for a wide range of therapeutic purposes for a vast range of neurological conditions (Hallett, 2007; Horvath et al., 2011). Previous pilot investigations have demonstrated the ability of TMS in the speeding up of reaction times in Parkinson's disease patients (Cunnington et al., 1996; Ghabra, Hallett, & Wassermann, 1999; Pascual-Leone et al., 1994; Pascual-Leone et al., 1995). Based on the findings from previous studies, this led to the establishment of rTMS as a therapeutic method for this disease (Hallett, 2007), with many therapeutic investigations focusing on targeting the motor cortex (Lefaucheur et al., 2004; Siebner et al., 1999, 2000). As well as Parkinson's, TMS has been used to treat other neurological illnesses such as aiding recovery following a stroke, when given repeatedly over the ipsilesional motor cortex (Khedr et al., 2005; Kim et al., 2006).

Furthermore, although the effectiveness of TMS has been previously demonstrated in the treatment of epilepsy, these limited investigations are only small scale and demonstrate minimal beneficial effects of TMS (Cantello et al., 2007; Fregni et al., 2006; Hallett, 2007). For example, a study conducted by Cantello et al. (2007), found that TMS demonstrated reductions of interictal discharges, but failed to show a deterioration in seizures in drug-resistant epilepsy.

In addition, due to the nature of TMS and the ability to alter brain functioning, this neurophysiological technique has been demonstrated to be beneficial in the treatment of various psychiatric conditions (Horvath et al., 2011). Generally, rTMS therapy is most extensively used for psychiatric conditions, in particular it has been vastly used as a treatment for depression (Abdelrahman,et al., 2021; Downar & Daskalakis, 2013; Kolbinger et al., 1995; Mantovani et al., 2012; Shinba et al., 2018). Furthermore, a few investigations have focused on rTMS therapy in Schizophrenia, but these have demonstrated limited success of TMS (Hallet, 2007). However, rTMS therapy has been found to help reduce auditory hallucinations when applied over the auditory cortex (Haraldsson et al., 2004).

More recently, rTMS has been used as an effective treatment therapy for eating disorders (Van Den Eynde et al., 2010), in particular AN (McClelland et al., 2016) (See Chapter 1.3.4.2). rTMS therapy has been used for various types of AN symptomatology such as eating behaviours and interoceptive sensations of fullness, targeting areas such as the DLPFC (McClelland et al., 2013; Van Den Eynde et al., 2013). Support for the use of rTMS in therapy for AN comes from a successful case of an individual who received rTMS over the DLPFC. After 20 sessions of rTMS therapy, this individual demonstrated reductions in comorbid depression and improved AN symptoms including weight gain (Kamolz, Richter, Schmidtke, & Fallgatter, 2008). Similarly, rTMS over the DMPFC for 20-30 sessions reduced AN symptomatology such as co-morbid depression (Woodside et al., 2020). Consistent trends have been observed regarding rTMS therapy in reducing AN symptomatology and increasing weight gain (Hall et al., 2018). Although shown to be successful, some single case studies have demonstrated lack of effectiveness of rTMS in improvement of AN symptomatology (Jaššová et al., 2018).

2.5.1.5 The limitations of TMS for research and therapeutic purposes

Similar to any experimental technique, TMS has limitations that should be reflected upon, before using this measure for experimental and therapeutic purposes. For example, one important limitation is the spatial resolution of TMS (Bolognini & Ro, 2010). This is due to TMS having a restricted availability of stimulation depth i.e., this technique cannot reach subcortical regions deep within the brain. This is consequent to the magnetic field lessening in intensity the greater the distance from the coil. As a result, TMS is mainly effective for stimulating cortical brain regions which are closer to the scalp, approximately 2 - 3 cm in depth below the scalp (Najib et al., 2011; Roth et al., 1991; Zangen et al., 2005). Due to the intensity of brain stimulation decreasing further away from the coil, it has been debated as to whether TMS has the capacity to stimulate subcortical structures (Zangen et al., 2005), with some researchers and therapists proposing the use of a H-Coil to enable deep brain stimulation for regions such as the Insula and Hippocampus (Samoudi et al., 2018; Zangen et al., 2005). In addition, TMS only has a spatial resolution of approximately 0.5-1 cm (Brasil-Neto et al., 1992; Thielscher et al., 2002). This means that TMS cannot be used to explore a specific function spatial structures below the cerebral cortex (Fusco et al., 2022; Thielscher & Kammer, 2002; Toschi et al., 2008).

Another limitation of TMS is that stimulation can cause auditory and somatosensory side effects, which is due to the changing magnetic field. This is due to each magnetic pulse producing noise such as clicking, which is louder if the region is closer to the ear and tapping sensations producing muscular contractions, which is more evident in ventral regions (Mennemeier et al., 2009). As a result, this may be distracting to participants and thus TMS may be unsuitable for specific experiments with sound or sensory components, as the sensations and noise produced by the coil may interfere with a subject's performance and responses on a task (Duecker & Sack, 2015). Although the case, TMS has been widely used and has successfully been utilised in various laboratory-based investigations, even those with sound components (Bestelmeyer et al., 2011; Collignon et al., 2009) and somatosensory components (Blankenburg et al., 2008; Case et al., 2016; Knecht et al., 2003). To control for this and to prevent any experimental confounds, it is important to use a control region which also has these side effects when stimulation is given (Gobell, Rushworth, & Walsh, 2006).

A third limitation is that TMS use is restricted as there are many safety protocols to follow in order to reduce risk to subjects (Horvarth et al., 2011; Rossi et al., 2021). As a result, using this technique means that often behavioural protocols need to be amended in order to comply with safety guidelines. This has major implications for study design, such as the length of the experiment, the number of trials of a stimulus, stimulation sites to be tested and the number of experimental conditions, as in some instances a minimum of 48hrs is required in-between testing sessions. In addition to experimental designs, clinicians for therapeutic interventions using TMS also need to take into consideration the number of trials, length of the session and stimulation sites to be tested. This can be overcome by splitting stimulation sessions to different sites on different days and keeping TMS stimulation to a shorter time window, so the effects of TMS are not eradicated before the end of the testing or therapeutic session (Rossi et al., 2009, 2021).

2.5.1.6 The safety of TMS as an experimental tool

The most important component of any TMS experiment or intervention is the safety of the subject or patient who is receiving stimulation. One important aspect to consider is that the magnetic field that is produced by TMS creates a loud clicking noise which can be distracting and uncomfortable for participants. In order to reduce these effects, it is recommended that ear plugs are used for all experiments (Rossi et al., 2009, 2021).

Some subjects or patients may experience headaches or nausea due to stimulation, neck pain due to pressure on the scalp. In addition, they may find twitching side-effects of TMS uncomfortable (Rossi et al., 2021). In order to overcome these side-effects, it is important that correct training is given to all personnel who wish to conduct any investigations or treatments using this technique (Rossi et al., 2021). Furthermore, any subjects or patients who report these sensations, should be able to end the receiving of stimulation and not feel obliged to continue. This is necessary for the health and safety of the individual, as well as reducing the chances of participants producing noisy data for research purposes (Rossi et al., 2021).

Although previously it was reported that TMS has more serious safety implications, in that it may induce an epileptic seizure (Rossi et al., 2009), more recent guidelines stated by Rossi et al. (2021) have in fact revealed that the risk of this is extremely low (only 41 cases reported worldwide; Chou et al., 2020) and the majority of those reported seizures occurred preceding the induction of safety limits (Rossi et al., 2021). It is therefore important that in order to reduce the risk of participants or patients experiencing a seizure, any individual with a history or family history of epilepsy or neurological conditions e.g., stroke should refrain from taking part in the investigation or treatment which is not aimed at targeting that specific condition (Horvath et al., 2011; Rossi et al., 2009, 2021; Stewart et al., 2001). In addition, to minimise this risk of a seizure, investigators should follow the internationally accepted and published protocol for TMS stimulation, such as the maximum intensity, frequency, duration, number of pulses and inter-trial intervals which do not pose any safety risks for participants (Horvath et al., 2011; Rossi et al., 2009, 2021; Wasserman, 1996). If an investigator stays within these protocol limits, conducting TMS in neurotypical individuals is believed to be safe and will not induce harm (Rossi et al., 2021). For clinical purposes, it is important that TMS treatment is carried out by a physician or trained personnel under the supervision of a physician (Rossi et al., 2021).

In general, previous evidence has indicated TMS is a beneficial technique to be incorporated into research to establish causative roles of brain region and functioning (Hallett, 2007; Horvath et al., 2011) and therapeutic purposes for treatment of an array of disorders (Horvath et al., 2011). If all safety protocols are adhered to, TMS is safe to administer and does not produce any dangerous or long-lasting side effects (Horvath et al., 2011; Rossi et al., 2021). Specifically, results from a pilot intervention conducted by Woodside et al. (2021) suggests that rTMS is safe to be administered to individuals with AN and may be beneficial in helping to alleviate some core AN symptomatology, when targeting brain regions such as the DMPFC. Overall, the findings from this pilot intervention emphasises the beneficial impact rTMS has in treatment interventions when conducted safely and correctly.

2.5.1.7 Repetitive TMS with theta-burst protocol (Study 4, Chapter 6)

Using a TMS technique, study 4 (Chapter 6) investigated whether inhibition of the right vmPFC and S1 is linked with atypical affective touch responses and if this is associated with reduced interoceptive awareness and ED symptomatology. All participants received offline rTMS with a theta-burst protocol delivered over the right S1, vmPFC and Vertex (Control region). This lasted 40 seconds per brain region (200 bursts, each comprising three pulses at 50% power, 30 Hz frequency, 6Hz burst frequency repeated every 200 ms (5 Hz), 600 pulses in total) as outlined in Goldsworthy et al. (2012). TMS occurred prior to the presentation of the observed affective touch videos. As a result, participants were required to attend three lab sessions, as the effect of each stimulation usually lasts over 1 hour. This prevented any confound of previous stimulation interfering with results from another brain region. This experiment involved three visits to the lab, in which participants were subject to all brain stimulation conditions which were counterbalanced.

During the brain stimulation phase, the intensity at which participants received this protocol to the S1, vmPFC and Vertex was 50% of power for 40 seconds. rTMS with a theta-burst protocol was delivered by a 70-mm figure-of-eight stimulation coil (Magstim Double 70 mm Air Film Coil), which is joined to a Magstim SuperRapid2 Stimulator (The Magstim Company, Carmarthenshire, Wales). This generated a magnetic field up to 0.8 T at the surface of the coil. In order for the accurate location of right S1, vmPFC and Vertex, a 3D brain reconstruction of each participant will be generated using the SofTaxic Navigator system (EMS, Bologna, Italy). During this procedure, participant's nasion, Inion, A1, and A2 and a series of 19 points generated over the participants scalp were located, for the system to be able to create a 3D construction of the participant's brain. This software allows for the manual input of the MNI and Talairach coordinates for brain areas of interest and pinpoints these coordinates on the 3D brain reconstruction, allowing for the accurate navigation with the coil (for more detail see section 2.5.2). Once the coil was placed over the scalp at the two areas of interest and vertex, the coil was held securely to the scalp of the participant ensuring the magnetic pulses were only given to the S1, vmPFC and Vertex.

Following the methodology of Pollatos et al. (2016) and Willacker et al. (2020), repetitive TMS with a theta-burst protocol was delivered over the right S1 at MNI coordinates (X= 46, Y= -28, Z= 72) (Case et al., 2016) and over the right vmPFC at Talairach coordinates (X= 3, Y= 58, Z= -8) (Davidovic et al., 2019). As a control site, the vertex was stimulated with the induced current running from posterior to anterior along the interhemispheric fissure at Talairach coordinates (X = 0, Y = −44, Z = 69) (Cazzato, Mele, & Urgesi, 2014; Jung et al., 2016), as this control region has demonstrated to display no differences in behaviour when no TMS was used as an additional control (Pitcher et al., 2008) (See Figure 2.5.1.7.1). For the theta-burst TMS protocol, TMS lasted 40 seconds (200 bursts, each comprising three pulses at 50% power, 30 Hz frequency, 6Hz burst frequency repeated every 200 ms (5 Hz), 600 pulses in total) as outlined in

Goldsworthy et al. (2012). The stimulation for the right S1, vmPFC and Vertex occurred prior to the observed affective touch task (For visualisation of study procedure, see Figure 2.5.1.7.2).

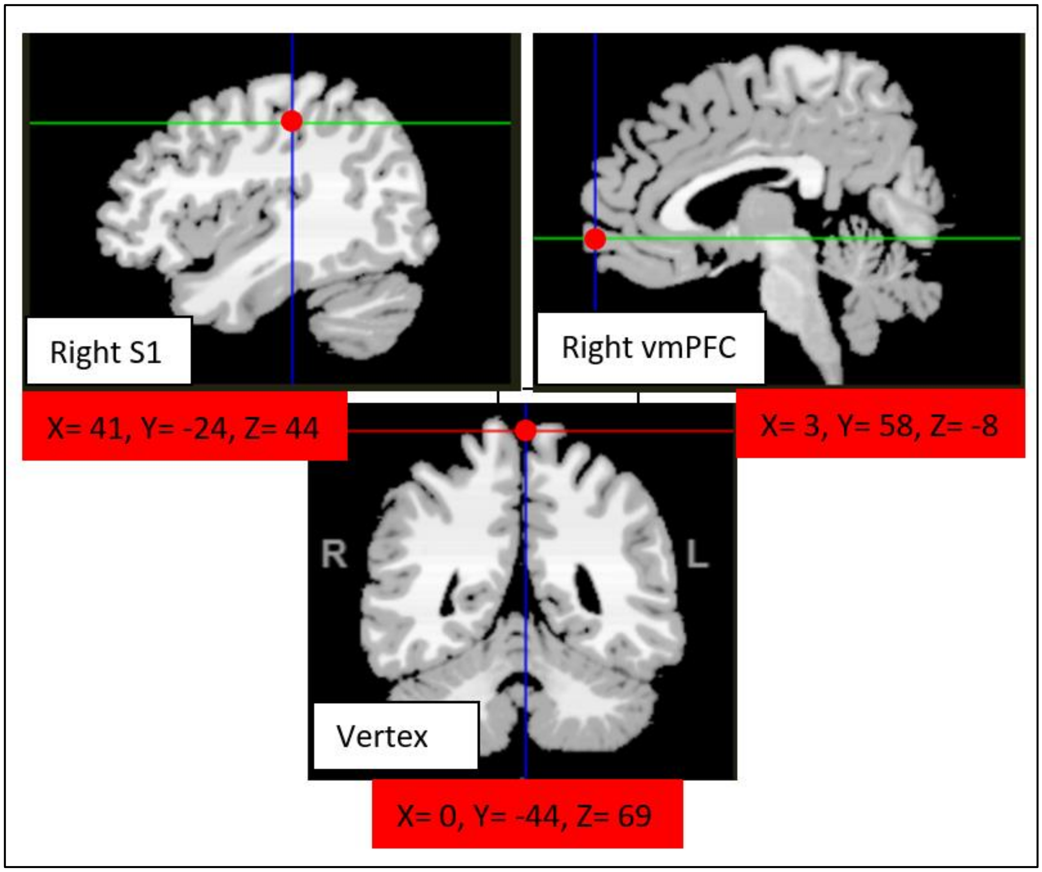

Figure 2.5.1.7.1. *MNI co-ordinates and location of the brain regions which will be targeted for study 4 (right ventro medial Prefrontal Cortex, right primary Somatosensory Cortex and Vertex (Control site)).*

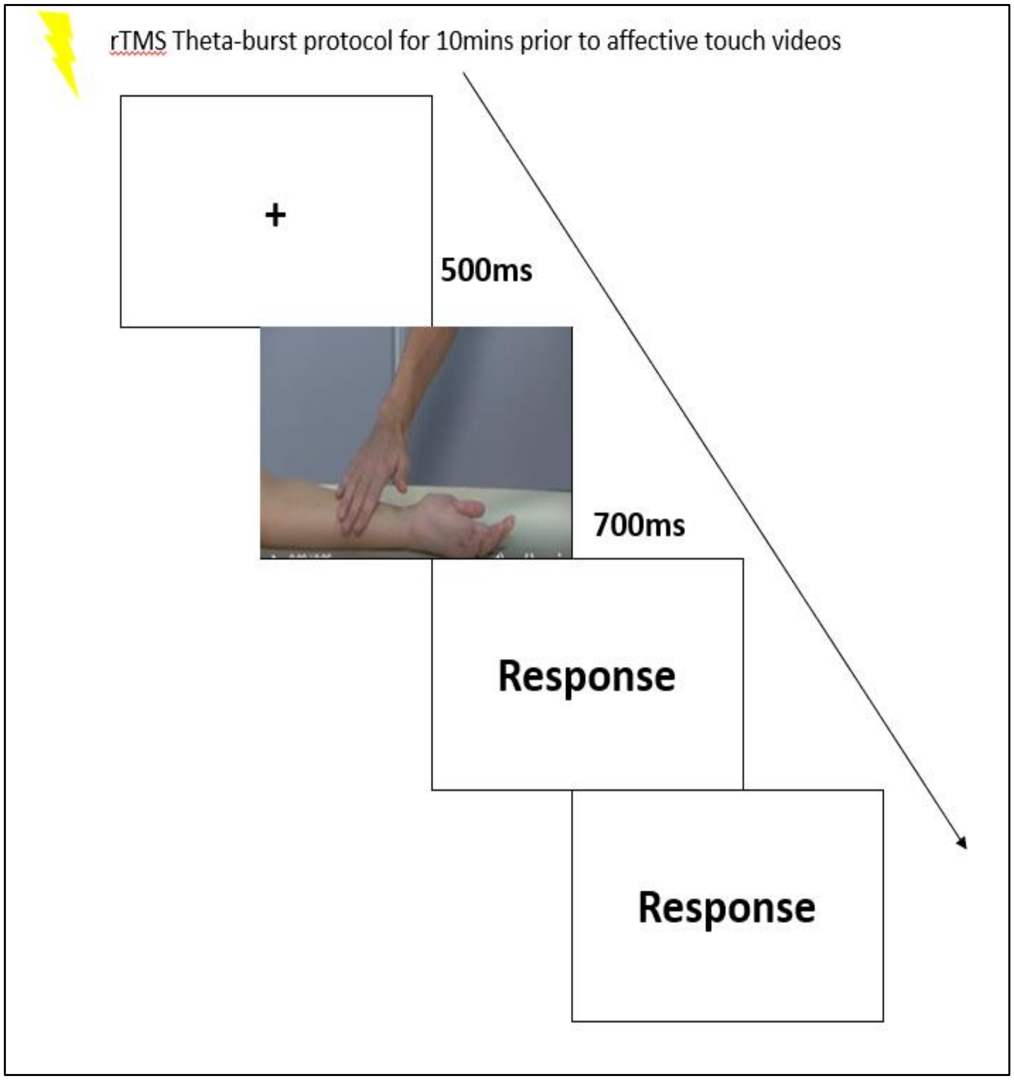

Figure 2.5.1.7.2. *Visualisation of the procedure for study 4 experiment for both the timing of the TMS theta-burst stimulation and the E-prime experiment which contains the observed affective touch videos described above.*

2.5.2 SofTaxic Neuronavigation System (Study 4, Chapter 6)

The SofTaxic Neuronavigation system was used in study 4 (Chapter 6), as this software can be used to accurately select and target cortical regions. This system guides the TMS coil to the exact location of the region of interest (Lioumis & Rosanova, 2022) such as the vmPFC, S1 and Vertex. Particularly for study 4 (Chapter 6), this system was used in multiple sessions for each participant, as their 3D brain reconstruction could be saved. This reduced any errors compared to using an EEG cap which may not be positioned the same way for each session. This system ensured replicable methods within and for each experimental session (Lioumis & Rosanova, 2022).

In general, Neuronavigation systems are a commonly chosen method to use in combination with TMS (Barker et al., 1985; Carducci & Brusco, 2012; Juleunen et al., 2009; Lioumis & Rosanova, 2022). These navigation systems use different tracking systems such as optical, ultrasound or magnetic, in conjunction with magnetic resonance images (MRI) to accurately position the TMS coil on the participant's scalp. This ensures that the stimulation is directed only to the brain region of interest (Carducci & Brusco, 2012). Study 4 incorporates the SofTaxic Neuronavigation System (E.M.S., Bologna, Italy) for the accurate localisation of brain regions of interest. The SofTaxic Neuronavigation system can be used in conjunction with an array of TMS models. The SofTaxic System consists of the SofTaxic Neuronavigation Software, for construction of MRIs and localisation using co-ordinates and the Optical Digitizer (NDI Polaris Spectra or Vicra), to pick up the TMS device and the participant's head in their surroundings. The SofTaxic system is used for research involving TMS and also in clinical settings by trained clinicians.

Before using the SofTaxic Neuronavigation System, the MRI of the participant is acquired and set up, which includes either importing the participants actual MRI taken prior to the session or if this is not possible, creating a reconstruction of an approximate MRI. To create an approximate MRI, a 3-Dimensional reconstruction of the subject's scalp is generated using an MRI standard template. Each MRI reconstruction is specific to the participant being tested i.e., this is adjusted based on the size and shape of the participant's scalp. A stylus is used to localise the nasion, Inion, A1 (left pre-auricular) and A2 (right pre-auricular). Proceeding from this, 19 points are localised using the 10-20 EEG system, for an accurate scale reconstruction (Carducci & Brusco, 2012). Once these steps are acquired participants are presented with an image of a participants MRI, which is used for the coil localisation.

Following on from the individual MRI reconstruction, individual MNI co-ordinates are entered into the system for the accurate pinpoint of brain regions for each participants generated MRI image, these can be entered into various forms such as Talairach. A target appears which allows researchers or clinicians to understand if they are close or far away from the brain region of interest. If the target is green and centred, this provides indication that the coil is positioned over the brain region, orange signifies that the coil is close to the targeted brain region and red demonstrates that the coil is at a significant distance from the brain region. In order to ensure that the coil remains over the brain region through the whole of the testing and stimulation phase, the target remains on the screen throughout the whole of the experimental session (Carducci & Brusco, 2012).

Chapter 3

Vicarious Ratings of social touch in typical populations at risk of an eating disorder

As discussed in Chapter 1.2, affective touch is typically evaluated as pleasant in healthy populations but as demonstrated in Chapter 1.3, this type of touch is perceived as less pleasant in clinical populations (Keizer et al., 2022), in particular in eating disorders such as AN and BN (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018; Bellard et al. 2022; Tagini et al. 2023). Nevertheless, there is currently no evidence concerning abnormal processing of vicarious affective touch since the majority of the studies have focused on real touch. Therefore, this current thesis focused on vicarious as opposed to actual touch in order to investigate the differentiation between self and other-directed touch in individuals with AN. This was examined as both types of touch require different neurocognitive mechanisms which may account for atypical responses to touch in people with AN. Specifically, if atypical responses in individuals with AN occur only when relating to self-directed touch or if this manifests when observed touch is given to another person.

Based on this, in the current study (Study 1), we investigated whether third-party vicarious ratings of social touch delivered at CT-optimal vs. CT non-optimal velocities differ in women reporting low and high EDs risk symptoms. We achieved this by administering social touch videos (Trotter et al., 2018a) which depicted interpersonal touch delivered at CT-optimal and non-CT optimal velocities which was self-directed and other-directed touch (See Chapter 2, section 2.1.1). To date, only three studies have investigated actual affective touch processing in high EDs risk, compared to healthy populations not at risk (Carey et al., 2019; 2021; Cazzato et al., 2021). Yet, no studies have investigated vicarious ratings of social touch in healthy groups with a high and low risk of an eating disorder. Furthermore, this study was conducted to understand baseline ratings of social touch and whether women who are at greater risk of an eating disorder also display negative responses to social touch similar to women with a diagnosis of an eating disorder. This study could offer insight as to whether atypical responses to affective touch occurs prior to the onset of an eating disorder or consequence to the post onset of an eating disorder.

3.1 Introduction

As outlined in Chapter 1.2, and according to the ‘Social Touch Hypothesis’, touch is pivotal for development, attachment, close social bonding, and communication with others. This is a form of non-verbal communication which involves positive, physical interaction with another (Bremner & Spence, 2017; Brauer et al., 2016; Cascio et al., 2019; Krahé et al., 2016; Morrison et al., 2010; von Mohr et al., 2017). The more an individual receives touch from another, the stronger the relationship they develop and maintain with the touch provider (Gallace & Spence, 2010). Touch is also key for the understanding of sense of self and is crucial for bodily ownership (Crucianelli et al., 2018).

Although there are individual differences in the perception of touch (Croy et al., 2020), CT-optimal touch typically results in greater perceived pleasantness (Ackerley et al., 2014; McGlone et al., 2014). This type of touch comprises of a distinctive neural pathway involved in affective and emotional processing, such as the Insula and Anterior Cingulate Cortex (ACC) (Gordon et al., 2013; Loken et al., 2009), which are activated both during the receiving of touch and perception of someone else receiving touch (Blakemore et al., 2005).

Nevertheless, as discussed in Chapter 1.3, despite this type of touch being perceived as most pleasant in neurotypical populations, the hedonic value of touch is perceived as unpleasant in psychiatric patients (Keizer et al. 2022). Recent research has provided evidence for impairment of the affective touch system resulting in atypical pleasantness ratings, in individuals with eating disorders such as AN (Crucianelli et al., 2016, 2019, 2021; Davidovic et al., 2018) and BN (Bischoff-Grethe et al., 2018). These investigations have found reduced pleasantness ratings in the actual receiving and prediction of the pleasantness of touch in these clinical populations (Bischoff-Grethe et al. 2018; Crucianelli et al., 2021). The disruption in the processing of affective touch has been regarded as a potential explanation for the aetiology and maintenance of symptoms of AN, such as body image distortions (Crucianelli et al., 2021). Yet, this explanation for the maintenance of this disorder requires further investigation.

Another key feature of this disorder is social cognitive deficits, including Theory of Mind (ToM) impairments (Gál, Egyed, Pászthy, & Németh, 2011; Hamatani et al., 2016; Russell, Schmidt, Doherty, Young, & Tchanturia, 2009; Tchanturia et al., 2018; Zucker et al., 2007). ToM is one's capacity to attribute internal states, such as feelings or intentions of another individual to understand their behaviour (Bora & Köse, 2016). An important component of ToM processing involves taking the perspective of another through comparing one own internal state (1st person perspective taking) to another (3rd person perspective taking), which are two separate constructs (Cooper & Mohr, 2012; Ruby & Decety, 2003). Evidence has suggested that individuals with AN have an impaired ToM (Bora & Köse, 2016; de Sampaio et al., 2013; Leslie et al., 2020; Oldershaw et al., 2010; Russell et al., 2009). For example, Happé et al. (1999) found that compared to heathy participants, those with AN demonstrated lower accuracy and took greater time to infer mental states to characters in cartoons. This impaired ToM is believed to manifest even after recovery due to an impairment in their social cognitive network (Bora & Köse, 2016; McAdams & Krawczyk, 2011). As implied by Bora and Köse (2016), ToM may impact AN individuals' engagement with talking therapies, as they may not correctly interpret therapists and the individual may have poor self-insight. As a result, this might hinder an individual's ability to access social support networks during their recovery process, due to their impaired social communication with others. Thus, it is vital to understand the nature of ToM difficulties in AN, to better understand the biological mechanisms surrounding their impairment, as well as to develop a more successful social-cognitive treatment intervention (Russell et al., 2009). In relation to affective touch, research has suggested that viewing others receiving touch induces touch experiences in the self and activates brain regions such as the Somatosensory Cortex and Insula Cortex (Masson et al., 2018). Given that previous studies have found reduced pleasantness in individuals with AN (Crucianelli et al., 2016, 2021; Davidovic et al., 2018), and that observing touch activates touch experiences and corresponding brain regions (Masson et al., 2017, 2018), it is anticipated that when the high EDs risk group are asked to rate the perceived pleasantness of others receiving affective touch, similar to people with AN, they will use their own negative experiences to interpret the feelings generated in another. It could be that high EDs risk individuals display no ToM impairments and no differences in ratings of social touch to the low EDs risk group, as found previously with individuals with AN and HCs (Adenzato, Todisco, & Ardito, 2012; Bora & Köse, 2016; Calvo et al., 2014; Medina-Pradas, Navarro, Álvarez-Moya, Grau, & Obiols, 2012). Nonetheless, it is not clear whether individuals with high EDs risk would also demonstrate similar ToM impairments and atypical responses to social touch as in people with AN, or whether they would display typical vicarious social touch responses comparable to that of HCs. Therefore, requiring further consideration and also to understand whether atypical responses to touch also extends to vicarious responses to social touch.

Furthermore, social factors such as exposure to touch are key in the top-down processing and individual differences which occur in the processing and evaluation of affective touch (Sailer & Ackerley 2019). As revealed in the study of Sailer and Ackerley (2019), the perceived pleasantness of touch varies depending on the frequency an individual's received touch. These researchers found that those individuals reporting lower levels of touch, had lower pleasantness ratings for CT-optimal touch and those with greater frequency of touch rated CT-optimal touch as most pleasant (Sailer & Ackerley, 2019). Neurotypical individuals who experience insecure attachment styles are more likely to report touch deprivation as these individuals receive lower levels of touch and show greater levels of longing for touch. Experiences of atypical touch experiences during childhood might play a part in these insecure attachment styles and greater levels of touch deprivation (Beltran et al., 2020). Thus, as outlined by Keizer et al. (2022), touch deprivation has shown to influence healthy individuals' experience of and response to affective touch. These individuals might demonstrate a reduced capacity in the discrimination between CT optimal and non-optimal affective touch (Krahé et al., 2018). This deprivation is believed to occur also in clinical population such as AN (Gupta et al., 1995) and also potentially in individuals with high EDs risk.

3.1.1 The Current Study

In two different tasks, we aimed to investigate whether third-party vicarious ratings of social touch delivered at CT-optimal vs. CT non-optimal velocities differed in women reporting low and high EDs risk symptoms. In order to measure this, participants viewed a series of video clips of touch being applied to various body sites (ventral forearm, upper arm, back, cheek and palm) at different velocities (0 cm/s, 5 cm/s and 30 cm/s). After each video, participants provided ratings in response to two questions, each one corresponding to one task, with one asking: “How pleasant do you think that action was for the person being touched?” (other-directed touch) and a second question asking: “How much would you like to be touched like that?” (self-directed touch) (Walker et al., 2017) (see Chapter 2.1.1).

Furthermore, this investigation aimed to examine whether individual differences in levels of eating disorder symptoms, as well as dysmorphic appearance concerns, body awareness and social touch experience may impact participants’ pleasantness ratings for specific body sites (Cazzato et al., 2021). Previous research has found that dysmorphic concerns is a key characteristic of AN, with higher dysmorphic concerns accounting for increased AN symptomatology (Beilharz et al., 2019). Women with AN have demonstrated interoceptive deficits such as interoceptive awareness, which includes reduced tactile pleasure (Crucianelli et al., 2021). Furthermore, Zucker et al. (2013) found that women with AN, both current and recovered, have an enhanced negative sensitivity to sensory experiences such as touch and they avoid receiving this sensory experience, i.e., they avoid touch from others both from known and unknown individuals (Zucker et al., 2013). Based on this, it was hypothesised that compared to low EDs risk females, high EDs risk females would have reduced wanting for touch, consequent to their atypical responses to touch, which will be associated with higher eating disorder traits, reduced interoceptive awareness, body image concerns and reduced social touch experience. As opposed to low EDs risk females, we expected that high EDs risk females would rate touch for another individual as less pleasant. Specifically, that they would use their own negative experiences to make judgements on the pleasantness of touch for another, given that this mechanism involves similar responses and activation of brain regions in both self and other-directed touch (Masson et al., 2018).

Moreover, it is important to note that the current study was conducted during the Covid-19 pandemic. At this time, several public health measures were implemented to prevent the spread of the virus, one of which being social distancing (Verity et al., 2020). The use of social distancing and global lockdowns resulted in fewer touch interactions, leading to self-reported touch deprivation (Field et al., 2020; von Mohr et al., 2021).

Previous research has found a link with social distancing measures and greater longing for touch (Hasenack et al., 2023; Meijer et al., 2022; Von Mohr et al., 2021) and overall wellbeing of an individual (Floyd, 2014). Based on touch deprivation during the Covid-19 pandemic, we also developed a COVID-19 questionnaire, based on findings from Branley-Bell and Talbot (2020), to control for socio-contextual factors which may impact pleasantness ratings. These factors which were controlled for included eating behaviours i.e., whether participants were eating more or less during this period and touch experiences with loved ones and strangers and levels of social isolation during the pandemic.

3.2 Methods

3.2.1 Participants

An original sample of 188 participants took part in this online study, hosted on Qualtrics (Version 60939 of the Qualtrics Research Suite. (Copyright © 2015 Qualtrics., Provo, UT, USA. http://www.qualtrics.com)). Participants were recruited through external contacts, via social media, the SONA system (an online platform allowing for the targeting of university participants in which they receive credit points for their time) and through those known to the researchers. A total of 103 participants were excluded from the analysis due to incomplete data sets.

The total final sample consisted of 85 healthy females (M_{age}= 23.51, SD= 8.40). A power analysis using G*Power 3.0.10 (Faul et al., 2007) indicated that a total sample of 80 participants was needed to detect a medium effect (f = .25) with 95% power, using a Linear Multiple Regression with alpha at .05 (two tailed with 4 predictors).

Participants were allocated to either the high EDs risk and low EDs risk group based on their scores on the EDE-Q total score, which is an index of the risk of developing an ED. The clinical cut off score was used to assign participants into groups, a score equal to and above 4 indicated high EDs risk and a score below 4 indicated low EDs risk. Specifically, 45 women (M_{age}= 22.84, SD= 8.56), with a BMI range of 17.3 to 43.8 (M= 25.66, SD= 5.12) reported high EDs risk symptoms vs. 40 women (M_{age}= 24.25, SD= 8.27), with a BMI range of 15.6 to 37.2 (M= 22.45, SD= 3.92) reported low EDs risk symptoms (see Table 1).

Participants were eligible to take part if they self-reported not to have any history or current diagnosis of any psychiatric or neurological disorders (including eating disorders and body dysmorphic disorder), were not pregnant, had normal/corrected to normal vision and did not suffer from any skin conditions (e.g., eczema), or chronic pain conditions. Eligibility for all participants was checked through a participant screening questionnaire and those who were not eligible were not able to proceed with the investigation (see methods below). Only females were used in the current investigation, because: a) they are typically more sensitive to touch discrimination and also respond more positively to touch than males (Russo et al., 2020), b) the incidence of eating disorders is greater in women than in men (Striegel-Moore et al., 2009). All participants were naïve to the true aims of the investigation. The study's aims were made clear when participants were debriefed through the debrief sheet presented at the end of the study.

The study was conducted in accordance with the Helsinki declaration of ethical standards. The study protocol was approved by the LJMU's University Research Ethics Committee (UREC) (protocol: 20/NSP/025). All participants gave their informed consent to take part in the study. Participants were offered the chance to voluntarily enter themselves into a prize draw, with two chances of winning a £25 Amazon voucher and level 4 (First year Undergraduate) BSc Psychology students were awarded course credits, as compensation for their time.

3.2.2 Measures

3.2.2.1 Observed affective touch videos

The affective touch rating task comprised of 6 second videos of one actor receiving touch from another actor. In this investigation the videos demonstrated a female actor receiving touch from a male actor to five body regions (Ventral Forearm, Upper Arm, Back, Cheek and Palm) (see Figure 3.2.2.1.1). This task was administered as described in Chapter 2 (see Chapter 2, section 2.1.1). In this study, each body part was shown only once, with both questions (see Chapter 2, section 2.1.2) being displayed after each video in a randomised order (Trotter et al., 2018a).

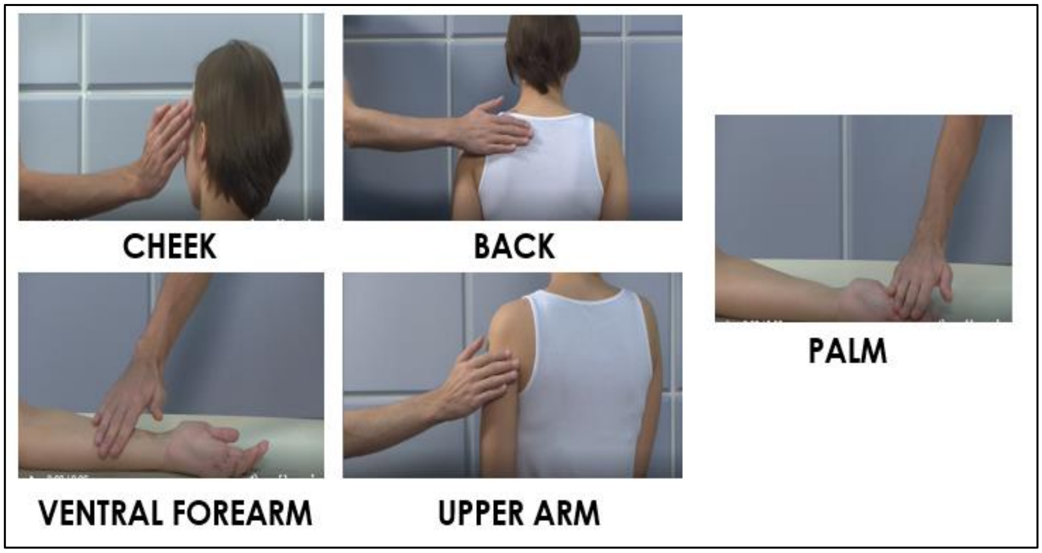

Figure 3.2.2.1.1 *Visual illustration of the 5 body sites (CT-innervated body regions: Ventral Forearm, Upper Arm, Cheek and Back vs. the non-CT innervated palm) from the affective touch videos used in this study.*

3.2.3 Self-report Questionnaires

3.2.3.1 Participant Screening

A set of seven screening questions was administered to participants to assess their suitability and eligibility to take part to the study. Participants were instructed to answer these questions by stating whether the statement provided was “true” or “false.” Statements provided included the following: “I am 18 years old or over.”, “I am female.”, “I do not suffer from any form of skin condition.”, “I do not suffer from any chronic pain condition.”, “I am not pregnant.”, “I have normal or corrected vision”. An additional statement was used in order for participants to consent to take part in the study and were instructed to agree if they wish to do so. To ensure participants did not have a current or previous diagnosis of AN, an additional question asked participants to self-report if they had formal diagnosis of ED and to state their diagnosis (if any).

If a participant responded by stating “false” to any of the seven statements listed above or did not click “I agree” to take part to the study, an “if then” function was applied. This function would prevent any ineligible participants from taking part and would direct this individual straight to the end of survey page, thanking them for their time.

This questionnaire ensured that participants not eligible for the study could not take part and most importantly, to be certain that individuals did not have or previously had an eating disorder (see appendix 1).

3.2.3.2 Demographics Questionnaire

Participants provided various demographic information such as their age, gender, biological sex, ethnicity, relationship status and education level. Participants were also asked to state their height (cm/ft) and weight (Kg/lbs) which was used to calculate their Body Mass Index (BMI) (see appendix 2).

3.2.3.3 Multidimensional Assessment of Interoceptive Awareness (MAIA) Questionnaire

The Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling et al., 2012) is a 32-item questionnaire which assesses eight components of interoceptive awareness (see Chapter 2, section 2.3.3). In this study, the MAIA questionnaire was administered to investigate whether facets of interoceptive awareness differed in individuals with high vs. low EDs risk (see appendix 3).

3.2.3.4 Eating Disorder Examination Questionnaire (EDE-Q)

The Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994) is a self-report questionnaire for the assessment of ED symptomatology (see Chapter 2, section 2.3.4). In this study, a cut off score of 4 or more was applied to assign participants in the high EDs risk group, a cut off below 4 was used to classify participants into the Low EDs risk group (Carter et al., 2001; Mond et al., 2006) (see appendix 4).

3.2.3.5 Dysmorphic Concern Questionnaire

The Dysmorphic Concern Questionnaire (DCQ) (Oosthuizen et al.,1998) is a short questionnaire used to measure an individual's concern towards their physical appearance (see Chapter 2, section 2.3.6). This was used to assess whether individuals with high EDs risk demonstrated more concern towards their physical appearance compared to individuals in the low EDs risk group (see appendix 5).

3.2.3.6 Touch Experiences and Attitudes Questionnaire

The Touch Experiences and Attitudes Questionnaire (TEAQ, Trotter et al., 2018b) is a questionnaire which measures experience and attitudes towards touch (see Chapter 2, section 2.3.7). This questionnaire assessed whether individuals with high EDs risk demonstrated a reduction in the experience of touch both currently from a partner, family, and friends and also during childhood and if this reflected a greater negative attitude towards touch compared to the low EDs risk group (see appendix 6).

3.2.3.7 COVID-19 touch experiences and eating behaviour Questionnaire

This questionnaire consisted of twelve questions and was designed to measure touch experience and eating behaviour since the current COVID-19 pandemic (see appendix 7). This questionnaire was administered to ensure touch deprivation during the Covid-19 pandemic did not influence touch pleasantness ratings at the time of data collection.

3.2.4 Procedure

3.2.4.1 General Procedure

Participants were provided with an invitation email, which contained a brief description of what the study entailed and the hyperlink to the online study if participants were happy to take part. Once clicked, participants were provided with the participant information sheet, screening questionnaire and gave their consent to take part. Once consent was obtained and eligibility was determined, participants were then asked to rate the affective touch videos, according to the two tasks: “How pleasant do you think that action was for the person being touched?” and “How much would you like to be touched like that?.” The order participants viewed the videos were counterbalanced, as well as the order the questions appeared proceeding each video. After completing the affective touch rating task, participants then filled out the above-described questionnaires, which assessed eating disorder risk, body image concerns, body awareness, body misperceptions, experiences, and attitudes to touch, as well as social isolation and longing for touch since the COVID-19 pandemic. The order participants filled out these questionnaires was counterbalanced. Overall, the online study lasted approximately 35 minutes. Data collection began on 10th July 2020 and ended on 2nd December 2020.

3.2.4.2 Statistical Analysis

All data were analysed using SPSS 26 (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.). All data were checked and were normally distributed. All demographic information and scores for the self-reported questionnaires are reported as Mean (M) and Standard Deviation of the mean (SD). Vicarious ratings of social touch were analysed using two 3-way Mixed ANOVAs with a between-subjects factor of Group (2 levels: high EDs risk and low EDs risk) and within-subjects factors of body sites (5 levels: ventral forearm, upper arm, back, cheek and palm) and velocity (0 cm/s, 5 cm/s and 30 cm/s). Both of these ANOVAs were separate for Task (self-directed touch and other-directed touch). A significance threshold of $p<.05$ was used for each of the post hoc comparisons and independent samples *t*-tests. All *p* values were corrected for multiple comparisons using Bonferroni correction.

Independent samples *t*-tests were conducted to measure group differences for all questionnaire subscales of the EDE-Q, MAIA and TEAQ. The differences between mean scores were assessed to see if groups significantly differed in scores for each individual subscale.

As also calculated in previous studies of Croy et al. (2016), a Pleasant Touch Awareness (PTA) index was calculated as the difference in pleasantness ratings between CT-optimal (5 cm/s) and CT non-optimal stroking (30 cm/s), weighted by the average scores calculated separately for each participant and location (PTA = (pleasantness ratings at 5 cm/s − pleasantness ratings at 30 cm/s)/overall touch pleasantness). This score was used to assess the level at which CT-optimal touch is preferred over CT non-optimal velocities (Croy et al., 2019). This was used to compare high EDs risk and low EDs risk preference for CT-optimal touch for each task individually. This score was used in a series of Pearson's correlations to understand if there was an association with TEAQ, MAIA and DCQ subscales on PTA scores for each group and separately for each task (self-directed touch and other-directed touch).

For exploratory purposes, we performed a series of exploratory Multiple Linear Regression analyses to investigate the predictive role of TEAQ, MAIA and DCQ subscales on PTA scores, for high EDs risk and low EDs risk separately for each task (self-directed touch and other-directed touch).

3.2.5 Results

3.2.5.1 Univariate Statistics

Table 3.2.5.1.1 demonstrates the means and standard deviations for the demographics and self-report questionnaire scores for high EDs risk compared to low EDs risk. The far-right column of Table 3.2.5.1.1 shows results of a pairwise comparison between both groups, adjusted with a Bonferroni correction. Surprisingly, high EDs risk had significantly higher BMIs than low EDs risk. High EDs risk scored significantly higher on all subscales on the eating disorder examination questionnaire. High EDs risk, compared to Low EDs risk, had greater dysmorphic concern and higher reported social isolation due to Covid-19. Low EDs risk reported significantly higher experience of their body as safe and trustworthy, compared to high EDs risk.

Table 3.2.5.1.1 Mean and standard deviation (in brackets) of demographics and self-report questionnaires scores for the high EDs risk (*n=45*) compared to the low EDs risk (*n=40*). The far-right column depicts Bonferroni corrected *p* values.

	High EDs risk (*n=45*) M (SD)	Low EDs risk (*n=40*) M (SD)	High vs. low EDs risk *P*
Age (years)	22.84 (8.56)	24.25 (8.27)	Ns
BMI (kg/cm^2)	25.66 (5.12)	22.45 (3.92)	.002
EDE-Q			
Restraint (max 6)	2.86 (1.36)	.62 (.72)	<.001
Eating Concern (max 6)	1.82 (1.42)	.26 (.28)	<.001
Weight Concern (max 6)	4.20 (1.16)	1.60 (.98)	<.001

Shape Concern (max 6)	3.98 (1.22)	1.05 (.83)	<.001
DCQ (max 21)	10.13 (4.90)	7.15 (4.19)	.004
MAIA			
Noticing (max 5)	3.57 (.80)	3.55 (.93)	ns
Not Distracting (max 5)	2.54 (1.13)	2.64 (1.13)	ns
Not Worrying (max 5)	2.48 (1.01)	2.45 (1.13)	ns
Attention Regulation (max 5)	2.96 (.95)	3.03 (.99)	ns
Emotional Awareness (max 5)	3.65 (.89)	3.49 (1.00)	ns
Self-regulation (max 5)	2.61 (1.27)	2.84 (1.25)	ns
Body Listening (max 5)	2.24 (1.20)	2.53 (1.34)	ns
Trusting (max 5)	2.77 (1.22)	3.36 (1.06)	.021
TEAQ			
Friends and family touch (max 5)	3.36 (1.06)	3.37 (1.01)	ns
Current intimate touch (max 5)	3.18 (.89)	3.01 (.93)	ns
Childhood touch (max 5)	3.98 (.90)	3.91 (.86)	ns
Attitude to self-care (max 5)	3.95 (.76)	3.82 (.78)	ns
Attitude to intimate touch (max 5)	4.02 (.68)	3.91 (.97)	ns
Attitude to unfamiliar touch (max 5)	2.53 (.77)	2.76 (.91)	ns
COVID-19			
Given in household (max 100)	29.33 (31.18)	26.73 (34.93)	ns
Received in household (max 100)	27.53 (31.74)	24.98 (31.72)	ns
Given to stranger (max 100)	75.41 (33.04)	71.05 (33.45)	ns
Received from stranger (max 100)	74.07 (31.06)	69.43 (34.89)	ns
Level of touch reduced (max 100)	61.56 (25.53)	68.63 (28.10)	ns
Touch wanting (max 100)	52.62 (24.72)	48.88 (23.20)	Ns
Eating behaviour (max 100)	54.87 (27.13)	59.53 (18.70)	Ns
Physical activity rate (max 100)	39.38 (25.57)	40.53 (28.57)	Ns

Social isolation (max 100)	67.07 (27.70)	45.31 (32.81)	.001

BMI Body Mass Index*; EDE-Q* Eating Disorder Examination Questionnaire; *DCQ* Dysmorphic Concern Questionnaire; *MAIA* Multidimensional Assessment of Interoceptive Awareness; *TEAQ* Touch Experiences and Attitudes Questionnaire; *ns* Not Significant

Additional demographic characteristics such as ethnicity, any neurological/psychiatric conditions, relationship status and education level are reported in Table 3.2.5.1.2. We conducted a Chi-square analysis between high and low EDs risk to investigate whether there were any significant differences in these characteristics. There were no significant differences for ethnicity ($\chi^2_3 = .14$; $p = .987$), neurological/psychiatric conditions ($\chi^2_3 = 1.16$; $p = .763$) and relationship status ($\chi^2_5 = 5.68$; $p = .338$) between both groups. There was a significant difference in education level ($\chi^2_5 = 15.03$; $p = .010$) between high and low EDs risk, with the low EDs risk group being more educated.

Table 3.2.5.1.2. Demographic characteristics of high EDs risk (*n=45*) and low EDs risk (*n=40*), which has been analysed by Chi-square.

	Group		
	High Risk *n* (%)	**Low Risk *n* (%)**	**Total *n* (%)**
Characteristic			
Ethnicity			
Caucasian	37 (82%)	33 (82.5%)	70 (82.4%)
Asian	4 (8.9%)	4 (10 %)	8 (9.4%)
Hispanic	1 (2.2%)	1 (2.5%)	2 (2.4%)
Mixed	3 (6.7%)	2 (5%)	5 (5.9%)
Neurological/Psychiatric conditions			
Depression	1 (2.2%)	0 (0%)	1 (1.2%)
Anxiety	2 (4.4%)	1 (2.5%)	3 (3.5%)
Depression and anxiety	1 (2.2%)	1 (2.5%)	2 (2.4%)
None	41 (91.1%)	38 (95%)	79 (92.9%)

Relationship status			
Single	21 (46.7%)	23 (57.5%)	44 (51.8%)
In a relationship	19 (42.2%)	12 (30%)	31 (36.5%)
Engaged	1 (2.2%)	0 (0%)	1 (1.2%)
Married	2 (4.4%)	5 (12.5%)	7 (8.2%)
Separated	1 (2.2%)	0 (0%)	1 (1.2%)
Not Specified	1 (2.2%)	0 (0%)	1 (1.2%)
Education Level			
High School Graduate	14 (31.1%)	2 (5%)	16 (18.8%)
College Graduate	18 (40%)	15 (15.5%)	33 (38.8%)
Foundation Degree	6 (13.3%)	5 (5.2%)	11 (12.9%)
Bachelor’s degree	4 (8.9%)	13 (32.5%)	17 (20%)
Master’s Degree	3 (6.7%)	4 (10%)	7 (8.2%)
Doctoral or Professional	0 (0%)	1 (2.5%)	1 (1.2%)

3.2.5.2 Vicarious ratings of self-directed touch

The 3-way mixed ANOVA of Group (2 levels: High EDs risk and Low EDs risk Females) x Velocity (0 cm/s, 5 cm/s and 30 cm/s) x Body site (5 levels: Upper Arm, Ventral Forearm and Palm) for pleasantness ratings for wanting to be touched, revealed a significant main effect of velocity [F (2,162) = 6.720, p = .002, ηp^2 = .077], with CT-optimal touch (5 cm/s) rated as significantly more pleasant than touch applied at CT non-optimal velocities 0 cm/s (p = .008) and 30cm/s (p = .034). No significant differences were observed between the two CT non-optimal velocities 0 cm/s and 30 cm/s (p = .408). There was also a significant main effect of body site [F (4,324) = 18.059, p < .001, ηp^2 = .182]. The upper arm was rated as significantly more pleasant than the cheek (p < .001) but significantly less pleasant than the back (p = .012). There were no significant differences in pleasantness ratings for the upper arm and ventral forearm (p = 1.00) or for the upper arm and palm (p = 1.00). For the ventral forearm, only a significant difference was observed between this body site and the cheek, with the ventral forearm being rated as more pleasant ($p < .001$). The back was rated as most pleasant overall compared to the upper arm ($p = .012$), cheek ($p < .001$) and palm ($p = .006$), but no significant differences were observed for the back and the ventral forearm ($p = .315$). The cheek was rated as significantly less pleasant than the upper arm ($p < .001$), ventral forearm ($p < .001$), back ($p < .001$) and palm ($p = .002$). The palm was rated as significantly more pleasant than the cheek ($p = .002$), but significantly less pleasant than the back ($p = .006$). No significant differences were observed for the palm and the ventral forearm ($p = 1.00$) and upper arm ($p = 1.00$).

The 2-way interaction between body site and velocity was significant [F (8,648) = 4.941, $p < .001$, $\eta p^2 = .057$, See Figure 3.2.5.3.1]. A post-hoc analysis revealed that touch delivered at CT-optimal (5 cm/s) velocity to the upper arm was not rated as significantly more pleasant than 0 cm/s ($p = .102$) or 30 cm/s ($p = .961$). Furthermore, for the upper arm, the velocity of 30 cm/s was rated as significantly more pleasant than 0 cm/s ($p = .043$). Touch delivered at 5 cm/s to the ventral forearm was rated as significantly more pleasant compared to 0 cm/s ($p = .002$) and 30 cm/s ($p = .002$). For the ventral forearm, there was no difference in pleasantness ratings for 0 cm/s and 30 cm/s ($p = .158$). Also, for the cheek, 5 cm/s was rated as significantly more pleasant than 0 cm/s ($p < .001$) and 30 cm/s ($p < .001$). No difference in pleasantness ratings for the cheek was observed for 0 cm/s and 30 cm/s ($p = .396$). For the palm, 5 cm/s was rated as significantly more pleasant than 0 cm/s ($p = .042$). There were no significant differences for the palm between 5 cm/s and 30 cm/s ($p = .060$) or 0 cm/s and 30 cm/s ($p = .546$). Moreover, there were no significant differences in pleasantness ratings for velocity for the back (all ps > .060).

There was no significant main effect of Group [F (1,81) = .000, $p = .998$, $\eta p^2 = .000$]. The 2-way interaction between body site and Group was not significant [F (8,324) = .867, $p = .484$, $\eta p^2 = .011$]. The 3-way interaction between velocity, body site and group was not significant [$F(8,648) = .797$, $p = .606$, $\eta p^2 = .010$].

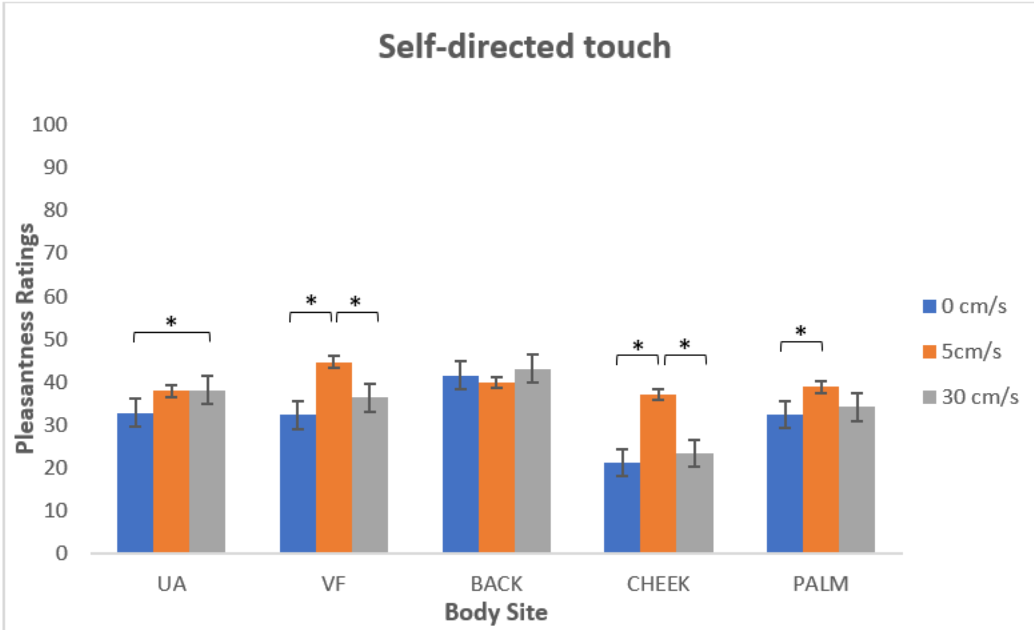

Figure 3.2.5.3.1 *Mean pleasantness ratings of touch delivered to five body sites (Upper Arm, Ventral Forearm, Back, Cheek and Palm) delivered at three velocities (0cm/s, 5cm/s, and 30cm/s) for self-directed touch ("How much would you like to be touched like that?") which has been compressed across both groups (high EDs risk and low EDs risk). Error bars represent standard error of the mean.*

We then conducted a series of Pearson's correlational analyses for all subscales of TEAQ, MAIA, DCQ and Covid-19 questionnaires for PTA scores for self-directed touch for High EDs risk females. Results revealed that PTA for the upper arm was significantly negatively correlated with the not worrying MAIA subscale (r = -.388, p = .010). PTA for all other body sites was not significantly correlated with any other factors (all ps > .083). For Low EDs risk, PTA for the back was significantly negatively correlated with emotional awareness (r = -.341, p = .036). PTA for the palm was significantly positively correlated with family and friends touch (r = .382, p = .015). PTA for all other body sites was not significantly correlated with any other factors (all ps > .134).

Additionally, several multiple regression analyses were conducted on PTA scores for self-directed touch, which have been calculated separately for each body site (Upper arm, ventral forearm, back, cheek and palm) and group. These analyses assessed whether eating disorder traits, dysmorphic concerns, interoceptive deficits and body awareness could account for pleasantness ratings both for high EDs risk females and low EDs risk females. For the high EDs risk females, regression analysis revealed that the model was not significant for the upper arm [F (10,41) = .906, p = .539], back [F (10,41) = .606, p = .796], cheek [F (10,40) = .889, p = .554], ventral forearm [F (10,41) = 1.791, p = .104] or palm [F (10,41) = .829, p = .605]. For the low EDs risk females, regression models were not significant for all body sites: upper arm [F (10,39) = .693, p = .731], ventral forearm [F (10,38) = .254, p = .933], back [F (10,38) = .384, p = .630], cheek [F (10,37) = .434, p = .890] and palm [F (10,38) = .944, p = .310].

To summarise, CT optimal touch was evaluated as most pleasant compared to CT-non optimal touch for all body regions excluding the back and upper arm for touch for the self. For high EDs risk, pleasantness ratings for touch directed towards the self was negatively associated with not worrying (which is one's ability not to have any experiences of emotional distress with physical discomfort). For low EDs risk, PTA for the back was associated with emotional awareness. For the palm, a positive association with experience of family and friends touch was observed. Covid-19 did not have an observed influence on pleasantness ratings for self-directed touch for any of the body sites and for both groups (See appendix 10).

3.2.5.4 Vicarious ratings of other-directed touch

The 3-way mixed ANOVA of Group (2 levels: High EDs risk and Low EDs risk) × Velocity (0 cm/s, 5 cm/s and 30 cm/s) × Body site (5 levels: Upper Arm, Ventral Forearm and Palm) for pleasantness ratings for touch for another, revealed a significant main effect of velocity [F (2,156) = 19.547, p < .001, ηp^2 = .200], with CT-optimal touch (5 cm/s) rated as significantly more pleasant than touch applied at CT non-optimal velocities (0 cm/s and 30 cm/s) (all *ps* < .033). No significant differences were observed between the two CT non-optimal velocities (p = .093). There was also a significant main effect of body site [F (4,312) = 4.908, p = .001, ηp^2 = .059] with the back being rated as most pleasant overall for another to be touched (all *ps* < .017). The upper arm, ventral forearm and palm were all rated as more pleasant than the cheek (all *ps* < .001). The ventral forearm was rated as significantly more pleasant than the palm ($p = .030$). There was not a significant main effect of Group [F (1,78) = .172, $p = .680$, $\eta p^2 = .002$].

The 2-way interaction between body site and velocity was significant [F (8,312) = 11.136, $p < .001$, $\eta p^2 = .125$, see Figure 3.2.5.4.1]. A Bonferroni post-hoc analysis revealed that touch delivered at CT-optimal (5 cm/s) velocity to the upper arm was not rated as significantly more pleasant than 0 cm/s ($p = .548$) or 30 cm/s ($p = .377$). Furthermore, for the upper arm, there was no difference in pleasantness ratings for 0 cm/s and 30 cm/s ($p = .112$). Touch delivered at 5 cm/s to the ventral forearm was rated as significantly more pleasant compared to 0 cm/s ($p < .001$) and 30 cm/s ($p < .001$). For the ventral forearm, there was no difference in pleasantness ratings for 0 cm/s and 30 cm/s ($p = .248$). Also, for the cheek, 5 cm/s was rated as significantly more pleasant than 0 cm/s ($p < .001$) and 30 cm/s ($p < .001$). No difference in pleasantness ratings for the cheek was observed for 0 cm/s and 30 cm/s ($p = .135$). For the palm, 5 cm/s was rated as significantly more pleasant than 0 cm/s ($p = .009$). There were no significant differences for the palm between 5 cm/s and 30 cm/s ($p = .054$) or 0 cm/s and 30 cm/s ($p = .178$). Moreover, there was no significant differences in pleasantness ratings for velocity for the back (all ps > .107).

The 2-way interaction between body site and Group was not significant [F (4,312) = 1.443, $p = .220$, $\eta p^2 = .018$]. The 2-way interaction of body site by velocity was not significant (all ps > .054). The 3-way interaction between velocity, body site and group was not significant [F (8,624) = .791, $p = .611$, $\eta p^2 = .010$].

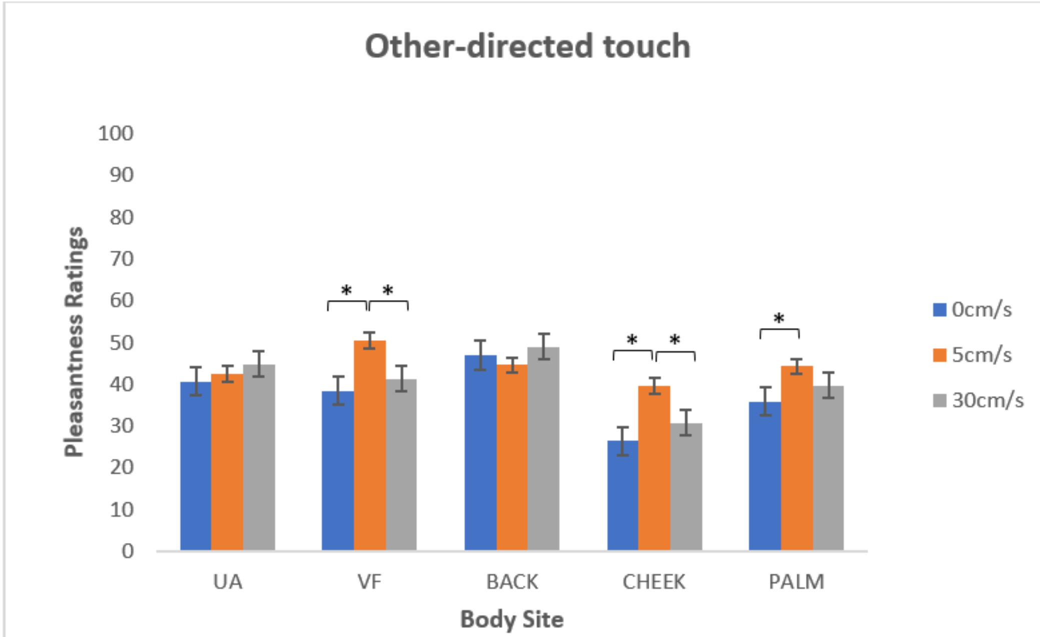

Figure 3.2.5.4.1. *Mean pleasantness ratings of touch delivered to five body sites (Upper Arm, Ventral Forearm, Back, Cheek and Palm) delivered at three velocities (0cm/s, 5cm/s, and 30cm/s) other-directed touch ("How pleasant do you think that action was for the person being touched?"), which has been compressed across both groups (high EDs risk and low EDs risk). Error bars represent standard error of the mean.*

We then conducted various Pearson's correlational analyses for all subscales of the TEAQ, MAIA, DCQ and Covid-19 questionnaires using PTA scores for other-directed touch for High EDs risk. Results revealed that PTA for the ventral forearm was significantly negatively correlated with emotional awareness (r = -.429, p = .004). PTA for all other body sites were not significantly correlated with any other factors (all *ps* > .098). For low EDs risk, PTA for the back was significantly negatively correlated with emotional awareness (r = -.377, p = .018). PTA for all other body sites were not significantly correlated with any other factors (all *ps* > .087).

Additionally, several regression analyses were carried out on PTA scores for other-directed touch, which have been calculated separately for each body site (Upper arm, ventral forearm, back, cheek and palm) and separately for each group. These analyses assessed whether eating disorder traits, dysmorphic concerns, interoceptive deficits and body awareness could account for pleasantness ratings both for high EDs risk and low EDs risk. For high EDs risk, regression analysis revealed that the model was not significant for all body sites: Upper arm [F (10,40) = .516, p = .182], ventral forearm [F (10,39) = 1.286, p = .284], back [F (10,40) = .789, p = .632], cheek [F (10,41) = .685, p = .730], and palm [F (10,40) = .899, p = .545]. Similar results were observed for the low EDs risk: Upper arm [F (10,38) = .590, p = .808], ventral forearm [F (10,39) = .397, p = .937], back [F (10,37) = .581, p = .815], cheek [F (10,37) = .571, p = .825], and palm [F (10,37) = .724, p = .622].

To summarise, CT optimal touch was evaluated as most pleasant compared to CT-non optimal touch for all body regions excluding the back and ventral forearm for touch for another person. Furthermore, although this investigation was conducted during the Covid-19 pandemic, this factor did not have any negative influence on overall touch pleasantness for any of the groups when making judgements for touch for another (see appendix 10). Instead, pleasantness ratings for touch for another for both groups was associated with emotional awareness, which for the high EDs risk was for the ventral forearm and for the low EDs risk, was for the back.

3.2.6 Discussion

To our knowledge, this is the first investigation to assess third-party vicarious ratings of social touch in women at high compared to low risk of an eating disorder. In two different tasks, we sought to investigate whether third-party vicarious ratings of social touch delivered at CT-optimal vs. CT non-optimal velocities differ in women reporting low and high EDs risk symptoms. Our analysis included covariates, such as eating disorder traits, interoceptive awareness, body image concerns and touch experiences and attitudes, which are factors which largely contribute towards the aetiology and development of EDs (Beilharz, Phillipou, Castle, Jenkins, Cistullo, & Rossell, 2019; Kaye et al., 2009; Nandrino et al., 2012; Strigo et al., 2013). We also took into consideration negative impacts Covid-19 had on females' pleasantness ratings of touch, to control for this contextual factor. We wanted to explore whether these covariates were predictors of pleasantness ratings for all body sites for third-party ratings of both pleasantness of touch for another (other-directed touch) and to the self (self-directed touch).

When comparing groups separately, both high and low EDs risk groups displayed comparable responses to vicarious social touch for the self. It was predicted that there would be clear observable differences, with high EDs risk females rating vicarious social touch as more unpleasant compared to low EDs risk. Instead, as unexpected, both groups rated CT-optimal touch as more pleasant compared to non-optimal velocities, which varied depending on the body site. It was expected that high EDs risk females would behave in a similar way to individuals with AN and would display atypical responses to affective touch (Crucianelli et al., 2016; Davidovic et al., 2018). Also, as outlined by Zucker et al. (2013), women with AN have an enhanced negative sensitivity to sensory experiences such as touch and consequently, avoid receiving touch from both known and unknown individuals (Zucker et al., 2013). Therefore, it was expected that high EDs risk would also show evidence of heightened sensitivity to touch. Yet, in the current study, high EDs risk females did not demonstrate reduced tactile pleasure or atypical responses to the touch they were observing. Instead, they displayed similar trends in ratings of vicarious social touch to the low EDs risk group. A potential explanation could be that women typically find touch of an unfamiliar male to be unpleasant, which is largely routed by sociocultural learning (Heslin et al., 1983) and regardless of their EDs risk, females in the current study may have rated touch similarly i.e., not as pleasant due to the male actor in the videos being unfamiliar. Nevertheless, although these findings do not offer support for previous research demonstrating atypical responses to affective touch in clinical and subclinical EDs populations (Cazzato et al., 2020; Crucianelli et al., 2016, 2021; Davidovic et al., 2018), results should be interpreted cautiously. Individuals in this study do not have a formal AN diagnosis and may reflect a population more representative of the general population. Based on this, it was important, as conducted in study 2 (see chapter 4), to assess atypical responses to vicarious social touch in women with a current and previous clinical diagnosis of AN in comparison to HCs.

Moreover, not only were there no group differences observed for touch wanting, but no group differences were also observed for third party ratings of pleasantness of touch for another and this was not predicted by eating disorder traits as expected. Prior research has suggested that individuals with AN have an impaired ToM (de Sampaio et al., 2013; Gál et al., 2011; Hamatani et al., 2016; Russell et al., 2009; Tchanturia et al., 2018; Zucker et al., 2007), which involves the decoding of affective stimuli (Bora & Köse, 2016) both at 1st person and 3rd person perspectives (Cooper & Mohr, 2012; Ruby & Decety, 2003). It was expected that, compared to low EDs risk females, high EDs risk females would demonstrate comparable responses to touch comparable to individuals with AN and use their own negative experiences of touch to interpret the feelings generated in another. However, high EDs risk females did not perceive CT-targeted touch as less pleasant than low EDs risk females. Instead, as found previously, no differences were observed between people with AN and neurotypical groups regarding their perspective taking when making inferences for touch for another (Adenzato et al., 2012; Bora & Köse, 2016; Calvo et al., 2014; Medina-Pradas et al., 2012). A possible explanation could be that the high EDs risk individuals displayed no ToM impairments and no differences in ratings of social touch to the low EDs risk group and offer support for the lack of differences between individuals with AN and HCs regarding ToM responses (Adenzato et al., 2012; Bora & Köse, 2016; Calvo et al., 2014; Medina-Pradas et al., 2012). Moreover, this lack of differences in pleasantness ratings between groups regarding touch to another person, may have occurred due to both groups displaying intact ToM processing and being more representative of the general population.

When assessing individual body sites, as expected, results demonstrated that perceptual tactile pleasantness of vicarious touch varied across body sites, with CT-optimal touch being rated as most pleasant for most body sites regardless of the task. Surprisingly, this was not the case for the upper arm and back, in which CT-non optimal velocities were rated as more pleasant compared to CT-optimal touch. Although the current study involved third-party ratings of touch rather than actual touch, unlike in Cazzato et al. (2020), ratings of touch for each body site did not follow a similar trend. This finding also goes against what was found previously by Walker et al. (2017), in which all body sites, excluding the palm, demonstrated clear preferences for CT-optimal touch compared to non-optimal touch. The lack of preference for CT-optimal touch for the upper arm was surprising considering this is a proximal region, which has been found to have a higher density of CT innervation compared to more distal regions (Löken et al., 2022). Therefore, it was expected that this region would show preference for CT-optimal touch. A possible explanation for this could be that, as found by Suvilehto et al. (2015), strangers are restricted to touch the hands only. In the current study, the touch provider was not familiar to any of the participants and as such, they may have evaluated touch to the upper arm, a region restricted to closer related individuals, as unpleasant to be touched from a stranger (Suvilehto et al., 2015). As found in Cazzato et al. (2020), Essick et al. (2010) and Löken, Evert, and Wessberg (2011), pleasantness of touch was also observed in the palm despite it being a glabrous skin site with sparse CT innervation (Essick et al., 2010; Morrison, 2016; Watkins et al., 2021). We also found an inverted U, whereby CT-optimal touch (5 cm/s) was rated as more pleasant for the palm, than non-optimal touch (Cazzato et al., 2020; Essik et al., 2010; Löken et al., 2011). However, in some instances, the palm was rated as more pleasant than CT-innervated body regions. For example, touch to the palm may be more pleasant as it is a common action between romantic partners and family, with handholding having pleasant effects, such as a decrease in the sensation of pain (Redden, Young, Falkner, Lopez-Sola, & Wager, 2020). It should be noted that almost half of the sample in the current investigation were in a romantic relationship, which could account for the higher than usual ratings for touch to the palm. Moreover, it could be also explained by Suvilehto et al. (2015), who highlighted that body regions such as the hand is a socially acceptable region to receive touch regardless of who is touching you i.e., a stranger (Suvilehto et al., 2015). A possible suggestion is that pleasantness of touch can still be rated as pleasant even for glabrous skin sites (Berridge & Kringelbach, 2008; Klöcker, Wiertlewski, Théate, Hayward, & Thonnard, 2013; Löken, Evert, & Wessberg, 2011; Rolls, 2010). It could be that top-down influences might have modulated participants' perception of touch to the palm (Berridge & Kringelbach, 2008; Rolls, 2010) as evidence has found activation of the Orbitofrontal Cortex (McGlone et al., 2012; Rolls et al., 2003), a brain region responsible for connecting affective experiences to hedonic value (Rolls, 2010). This brain region has been found to be activated in response to touch to both hairy and glabrous skin sites (Rolls, 2010).

Moreover, emotional awareness (a subscale of the MAIA which measures understanding the interrelatedness between bodily sensations and emotional states; Mehling et al., 2012), did not predict touch pleasantness for another. This was expected given that metacognitive awareness as measured by MAIA (Mehling et al., 2012) is related to understanding bodily signals for the self and not another person.

Furthermore, it was anticipated that Covid-19 would influence touch pleasantness, given that touch deprivation and greater longing for touch arose due to social distancing measures implemented (Field et al., 2020; Hasenack et al., 2023; Meijer et al., 2022; Von Mohr et al., 2021). In the current study, Covid-19 did not display any influence on pleasantness ratings for touch directed towards the self or another person. In particular, it was expected that stranger touch would be a significant predictor of pleasantness of touch regardless of task and this would be apparent in regions such as the cheek and hands. This was anticipated given that during the Covid-19 pandemic, individuals reduced their touching behaviours to areas of the face (Chen et al., 2020), this was due to the restrictions imposed, as touching the face increased transmission. The reduction in face-touching was expected to have had negative impacts on participants' perceived pleasantness of touch to the cheek. It could be that in the current study, participants were not exposed to direct touch and therefore the potential reduction in pleasantness ratings did not occur when viewing vicarious social touch.

Although this study was the first to assess third-party ratings of social touch in high compared to low EDs risk females, limitations have been identified. The results from this study should be handled cautiously due to the utilisation of self-report measures. It is not possible to ascertain participants' truthfulness when reporting their responses, especially for online investigations (Ridge et al., 2023). Thus, lack of group differences could possibly be due to participants not being truthful regarding questions concerning eating disorder behaviours, and therefore some of the low EDs risk females, may have been high EDs risk. Therefore, due to the difficulty in making solid conclusions and connections with affective touch processing in AN, study two aimed to understand vicarious ratings of social touch in women with a formal diagnosis of AN and recovered from AN, compared to a healthy control group with no EDs risk (See chapter 4).

3.2.6.1 Conclusions

Overall, findings suggest that third-party ratings of touch pleasantness do not differ between neurotypical females and those at heightened ED risk. Thus, individuals with high EDs risk do not display atypical responses to social touch, as experienced in individuals with AN. Based on this finding, it could be suggested that brain structural changes must occur in people with AN to alter their experience of touch and this may arise as a result of factors associated with AN symptomatology such as cerebral atrophy, which in turn may occur due to a reduction in brain mass as a result of severe starvation (Gołębiowska et al., 2022).

Therefore, the lack of differences in the current study could have occurred due to these females not having a formal diagnosis of AN and these females being typical of a healthy general population. Therefore, in study 2 (Chapter 4) we aimed to overcome the limitation of participants not having a formal diagnosis of AN, and further investigated this phenomenon using clinically diagnosed AN groups (both current and recovered AN; see chapter 4) .

Chapter 4

Vicarious Ratings of Self vs. Other-directed Social Touch in Women with and Recovered from Anorexia Nervosa

As discussed in Chapter 1.3, affective touch processing is suggested to be atypical in individuals with AN, with these populations rating affective touch as less pleasant compared to healthy controls (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018; Tagini et al., 2023). These atypical responses to receiving affective touch has found to manifest even after recovery from AN (Bischoff-Grethe et al., 2018). Nonetheless, there is an ongoing discussion as to whether the affective touch system in AN is impaired, given that different studies have provided contrasting evidence (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018; Tagini et al., 2023).

In the current study (Experiment 2), we investigated whether third-party vicarious ratings of social touch delivered at CT-optimal vs. CT non-optimal velocities differ in women (self) reporting AN or RAN, as compared to a healthy control group. We achieved this using social touch videos (Trotter et al., 2018a) which depicted touch being delivered at CT-optimal and non-CT optimal velocities (See Chapter 2). Only a limited number of studies have investigated affective touch processing in AN (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018), in particular, to understand if this process is atypical in individuals with a current and remitted diagnosis. Therefore, requiring further investigation. Based on this, study 2 focused on clinical populations rather than EDs risk (study 1), which aimed at providing a proof-of-concept as to whether women with a clinical diagnosis of AN or currently in remittance from AN, displayed less pleasant responses to social touch, atypical from healthy populations.

4.1 Introduction

As outlined in Chapter 1.3, AN is an eating pathology in which individual's display body image distortions (overestimation of their size) as well as body image concerns (Beilharz et al., 2019; Cazzato et al., 2016; Urgesi et al, 2014). Individuals with

AN typically display an overwhelming fear of gaining weight (APA, 2013) and have body image concerns and fear of weight gain. People with AN display abnormal eating and dieting behaviours such as starvation or purging, to maintain an unhealthy and low body weight (APA, 2013). Also due to the malnutrition of restricted food intake, people with AN typically display both cognitive and physiological consequences such as an impaired decision making (Zakzanis et al., 2010) and social cognition (Caglar-Nazali et al., 2014). Another key characteristic of this condition is deficits in interoception and lack of understanding internal sensations such as pain and hunger (Kerr et al., 2016; Martin et al., 2019; Strigo et al., 2013), which is believed to contribute towards body image distortions (Gaudio et al., 2014). Thus, this mismatch between internal and external processing in AN may contribute towards their aetiology (Kaye et al., 2009), yet this remains unknown.

Nevertheless, research examining altered interoception in individuals with AN has focused on unpleasant (pain), neural (heart rate) or symptom-specific signalling (hunger). Yet, affective touch processing, a form of positive interoception, involves different afferent fibres and is associated with slow conducting, unmyelinated C-Tactile (CTs) afferents, which are present only on the hairy skin (Ackerley et al., 2014; Liu et al., 2007; Löken et al., 2009; McGlone et al., 2014; Woodbury et al., 2001) and respond specifically to gentle stroking with velocities of 1-10 cm/s (Löken et al., 2009). CTs are important in body awareness and guiding behaviour and social interactions and thus may be abnormal in AN (Badoud & Tsakiris, 2017; Craig, 2002; Tsakiris, 2017). These afferents project to the posterior insula cortex, which has been identified as the hub for the evaluation of interoceptive stimuli (Craig, 2002; Gordon et al., 2013; Morrison, 2016). Therefore, affective touch might be considered a form of interoception, facilitated by the activation of the insula cortex, to process the hedonic and social value of the touch received (Krahé et al., 2018).

Research into the links between affective touch processing and AN symptomatology are limited. Recent research has provided evidence for the impairment of the affective touch system in individuals with AN (Crucianelli et al., 2016, 2021; Davidovic et al., 2018). These investigations have found reduced pleasantness ratings in the receiving and prediction of pleasant touch in this clinical population (Bischoff-Grethe et al. 2018; Crucianelli et al., 2021). A study conducted by Crucianelli et al. (2016) revealed that patients with restrictive-type AN displayed no differences in ratings of CT non-optimal touch compared to healthy controls. Yet, they rated CT-optimal touch as less pleasant than healthy controls. In support, similar findings were also observed by Davidovic et al. (2018), in which people with AN displayed significantly lower pleasantness ratings when receiving CT-optimal touch compared to healthy controls. Therefore, both studies suggest that abnormalities in affective touch processing occurs when touch is given at CT-optimal compared to CT non-optimal velocities. On the contrary, in the study by Crucianelli et al. (2021), both individuals with AN and RAN anticipated and rated touch at a CT non-optimal velocity as unpleasant, which was not observed for CT-optimal touch. Furthermore, Bischoff-Grethe et al. (2018), observed no differences between recovered AN and healthy control populations in both the anticipation and perception of affective touch. Thus suggesting that this impairment manifests only when an individual is currently experiencing AN, offering a potential explanation that this is key in the maintenance of AN symptomatology. All studies offer vital findings and understanding in affective touch processing in AN. Nevertheless, there are only four studies to date (Bischoff-Grethe et al. 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018) and therefore more research is required to address any inconsistencies in findings.

There is converging evidence to suggest that a key characteristic of AN is social cognitive deficits (Schmidt et al., 1995; Godart et al., 2004; Russell et al., 2009), specifically ToM impairments (Gál et al., 2011; Hamatani et al., 2016; Konstantakpooulos et al., 2020; Russell et al., 2009; Young, & Tchanturia, 2009; Tchanturia et al., 2018; Zucker et al., 2007). ToM is one’s ability to engage in complex social interactions through the attribution and inference of mental states of another individual in order to understand their behaviour at a given moment (Tchanturia et al., 2004). To achieve this, one must decode affective stimuli (Bora & Köse, 2016). An important process involved in ToM is perspective taking, which is when an individual uses their own state (1^{st} person perspective) to compare with another individual (3^{rd} person perspective) (Cooper & Mohr, 2012; Ruby & Decety, 2003). There has been previous evidence to suggest that perspective taking is key to ToM impairments in individuals with AN. In the study by de

Sampaio et al., (2013), twenty-four women with AN, 24 with Bulimia Nervosa (BN) and 24 HCs completed the ‘Reading the Mind in the Eyes Task’ and the ‘Faux Pas Test’ to measure theory of mind and the Rey-Osterrieth Complex Figure Test which was used to measure central coherence- the ability to comprehend a meaning from an array of different information. It was revealed that individuals with AN had a decreased central coherence and a deficient performance was observed on the ‘Reading the Mind in the Eyes Task’. Thus, suggesting that individuals with AN have a decreased ToM compared to HCs. fMRI studies have also revealed that even after recovery, people with AN have reduced functioning in the social cognitive network, compared to healthy controls, which can account for their difficulty in ToM perspective taking (Bora & Köse, 2016; McAdams & Krawczyk, 2011).

In relation to affective touch, research has suggested that viewing others receiving touch induces touch experiences in the self, activating regions such as the Somatosensory Cortex and Insula Cortex, which respond to touch to the self (Masson et al., 2018; Morrison et al., 2011). Given that previous studies have found reduced pleasantness in individuals with AN (Crucianelli et al., 2016, 2021; Davidovic et al., 2018), and that observing touch activates touch experiences and corresponding brain regions (Masson et al., 2017, 2018), it may be plausible to think that when people with AN are asked to rate the perceived pleasantness of others receiving affective touch, they will use their own ‘learned’ sensorimotor and visual experiences to interpret the feelings generated for another. However, it is not clear whether individuals with AN display ToM impairments, as conflicting research has found no differences with healthy control groups (Adenzato, Todisco, & Ardito, 2012; Bora & Köse, 2016; Calvo et al., 2014; Medina-Pradas, Navarro, Álvarez-Moya, Grau, & Obiols, 2012), therefore requiring further consideration.

4.1.1 The Current Study

The present study aimed to investigate whether third-party vicarious ratings of affective touch provided at CT-optimal vs. CT non-optimal velocities differed in women reporting a current diagnosis of AN. Similar to study 1, participants were subject to a sequence of videos with affective touch being delivered to several body areas of a female actor. After viewing each video, participants answered two questions: "How much would you like to be touched like that?" (self-directed touch) and "How pleasant do you think that action was for the person being touched?" (other-directed touch). It was anticipated that compared to healthy controls, patients with AN would evaluate vicarious self-directed tactile stimuli as less pleasant than other-directed touch. Importantly, we also recruited recovered AN (RAN) individuals to examine whether the differences in self- vs. other-directed third-party ratings hypothesised in people with AN as explained above, may also apply to recovered patients in comparison to HCs. Indeed, by testing women who have recovered from AN, it is possible to draw more solid conclusions about whether any potential abnormality observed in processing tactile pleasure are a cause or a consequence of starvation, thus ruling out the impact of malnutrition in the acute stages of illness which can cause cognitive and emotional deficits.

Furthermore, we aimed to explore whether specific dimensions of body awareness and of social touch experiences, may predict patients' third-party vicarious pleasantness ratings of touch when delivered to self, compared to when delivered to others (Badoud & Tsakiris, 2017). To meet this aim, we focused on the 'Trusting' subscale of the Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling et al., 2012) given that a previous work by Brown et al. (2017) reported that lower trust in one's body signals was most robustly associated with EDs psychopathology including higher restraint, eating concern, weight and shape concern, and binge eating and purging symptoms. Furthermore, a recent study confirmed that items from the MAIA Trusting subscale were the most central in bridging interoceptive awareness and ED symptoms (Brown et al., 2020). We also focused on the 'attitude to intimate touch' subscale of The Touch Experiences and Attitudes Questionnaire (TEAQ) (Trotter et al., 2018) because previous research reported that AN patients experience intimate stimuli with lower valence and dominance than healthy controls (Maier et al., 2019). Furthermore, women suffering from disordered eating report difficulties experiencing closeness with a partner and low levels of satisfaction in relationships (Evans & Wertheim, 1998). They also express a fear of intimacy (Fabello, 2020; Pruitt et al., 1992) and report avoidance of interpersonal relationships with men (Thelen et al., 1990) due to their lack of ability to form safe and close emotional bonds with others and struggle in maintaining romantic and sexual relationships (Fabello, 2020).

In line with previous evidence demonstrating blunted responses to actual touch experience (Bischoff-Grethe et al. 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018), it was hypothesised that self-directed touch would be less pleasant than other-directed touch for patients with AN compared to healthy controls. On the contrary, in the case of other-directed touch, it was hypothesised that ratings of pleasantness may be in line with controls and RAN women' responses due to a 'learned effect' of the tactile experience as rewarding/pleasurable. Accordingly, it might be plausible that when observing others receiving touch, people with AN might be using a learned experience of touch as pleasant for others, to guide their interpretation and inferences of pleasantness (Korkmaz, 2011). Finally, we hypothesised that scores obtained for the MAIA Trusting and to the TEAQ Attitude to intimate touch scales would predict pleasantness ratings for self-directed touch, for both individuals with AN and RAN, but not for HCs.

4.2 Methods

4.2.1 Participants

A total of 20 individuals with AN were excluded from the analysis due to not meeting the criteria of a BMI of 20 or below as proposed by the British Royal College of Psychiatrists (Ranta et al., 2017). A total of 2 people with RANs were also removed due to their extreme BMIs (above 2.5 standard deviation). An additional 3 people with RAN were removed due to having a BMI below 18.5 which is a classification criterion for AN and therefore there is a chance these participants are not fully recovered or are relapsing. Furthermore, 8 HCs were excluded due to not meeting the criteria of having no psychiatric conditions, which could impact responses to both the evaluation of videos and questionnaire responses. A total of 15 participants were excluded due to incomplete data sets, due to exceeding the cut off of a 2.5 SD analysis for evaluation responses to the observed affective touch videos. Those participants with 10 or more outliers in responses and those with repetitive responses across both questionnaires and evaluation of videos were eliminated.

A final sample of ninety-one female participants were recruited for this online investigation, of which were all assigned to one of three groups: current AN, recovered AN and healthy controls. This assignment was based on their self-reported AN diagnosis of either stating having a current diagnosis of AN, previous diagnosis of AN or indicating to have no current or previous AN diagnosis. The total sample size required for this study was based on a power analysis calculation using G*Power 3.0.10 (Faul et al., 2007). This result indicated a minimum number of 81 participants required in order to achieve a Mixed ANOVA analysis with a medium effect ($f = .25$) and 95% power, with alpha at .05 (two tailed).

This investigation consisted of only female participants, given that females are generally more sensitive to discrimination of touch and find touch to be more rewarding than males do (Russo et al., 2020). Furthermore, it was important to focus only on females given the greater incidence of eating disorders in females as opposed to males (Striegel-Moore et al., 2009). Twenty-seven were current AN aged 18-47 (M= 25.56, SD= 6.95) and with a mean BMI of 17.58 (SD=1.64) (see Table 4.2.5.1.1). Key information concerning the type of treatment currently being provided and the numbers of years diagnosed for this group are reported in Table 4.2.5.1.2.

A further 29 females were assigned to the remitted AN group. All females were aged 18-47 (M= 27.31, SD=7.12), with a mean BMI of 22.59 (SD= 3.03) (see Table 4.2.5.1.1). Additional information regarding number of years recovered is reported in Table 4.2.5.1.2.

A third group consisted of 35 female controls (M_{age}= 27.20, SD = 8.81; M_{BMI}= 24.77, SD= 4.47), who were recruited for the healthy control group (see Table 4.2.5.1.1). Participants for this group were contacted through external contacts, those known to the researchers and were recruited through social media platforms such as Facebook, Twitter and Reddit and the University SONA participant recruitment scheme. Importantly, healthy controls were eligible to participate if they stated they had no current or previous diagnosis of an eating disorder or body dysmorphic disorder. Another vital inclusion criterion participants in this group had to meet was to have no other neurological or psychiatric disorder. No other constraints were required from participants, as for this group we wanted a true representation of the non-eating disordered female population, many of whom have concerns about body image (Mond et al., 2006).

Both clinical groups (AN and RAN) were recruited through Gatekeeper permission i.e., through contacting eating disorder charities such as Beating Eating Disorders Organisation (BEAT) and MQ Mental Health Research. In addition, participants were also contacted through clinicians known to the researchers, who collaborate directly with these patient groups. In addition, individuals with AN and RAN were also contacted through AN support and recovery groups on social media, through permission from the administrator of the group. Importantly, a primary diagnosis of AN, as outlined in the DSM-5 (APA, 2013) was needed for patients to qualify for the study such as an extremely low BMI, restricted food intake resulting in rapid weight loss, fear of gaining weight, compulsive exercising, and body image concerns. In addition to this, we combined scores obtained from the Eating Disorder Examination Questionnaire (EDE-Q), a self-report questionnaire developed from the Eating Disorder Examination (EDE) structured interview (Fairburn & Beglin, 1994), as a screening for participants' eating behaviours.

The inclusion criteria for all participants, regardless of group was that they needed to have normal or corrected to normal vision (individuals with contact lenses or glasses were able to take part). It was also essential that these participants were not pregnant, did not suffer from any skin conditions such as eczema or any chronic pain conditions such as fibromyalgia. In order to assess eligibility to take part, participants completed an online screening questionnaire prior to study commencement.

All participants provided implied informed consent to partake in the investigation and were provided with a full debrief of the study through a debrief sheet, displayed at the completion of the study. All participants were offered compensation for their time taking part, such as the chance to voluntarily enter themselves into a prize draw, with two chances of winning a £25 Amazon voucher and level 4 BSc Psychology students were awarded with course credits. The study was conducted in accordance with the Helsinki declaration of ethical standards. The study protocol was approved by Liverpool John

Moores University (LJMU)'s University Research Ethics Committee (UREC, protocol: 20/NSP/025).

4.2.2 Measures

4.2.2.1 Observed affective touch videos

The affective touch rating tasks consisted of 6-second-long videos of a female actor receiving touch from a male actor. In these videos, touch was given to five body regions of the female actor including the ventral forearm, upper arm, back, cheek and palm (for a visualisation see Figure 4.2.2.1.1).

This task was administered as described in Chapter 2 (see Chapter 2, section 2.1.1). In this study, each body part was shown only once with both questions (see Chapter 2, section 2.1.2) being displayed after each video (Trotter et al., 2018a).

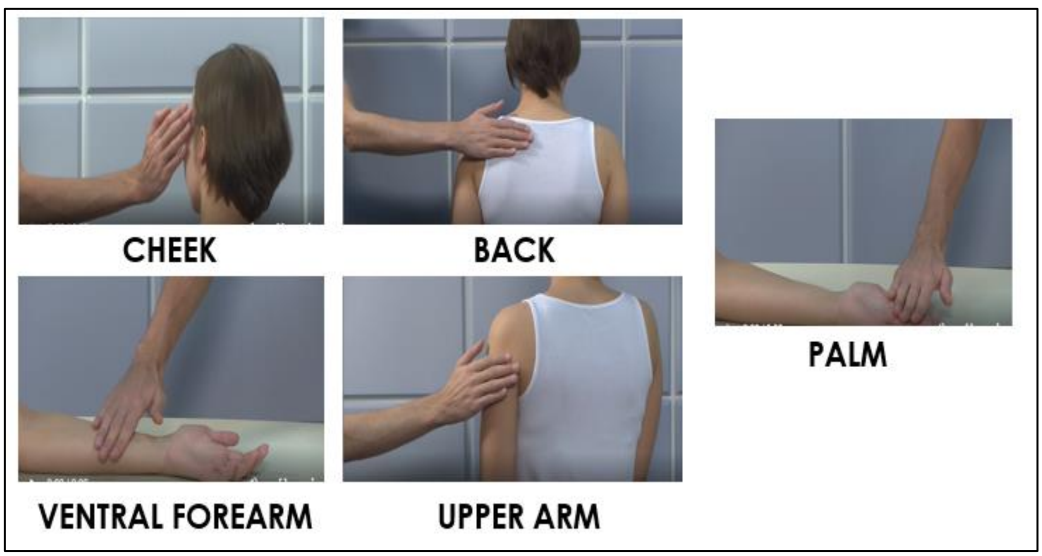

Figure 4.2.2.1.1 *Visual illustration of the 5 body sites (CT-innervated body regions: Ventral Forearm, Upper Arm, Cheek and Back vs. the non-CT innervated palm) from the affective touch videos used in this study.*

4.2.3 Self-report Questionnaires

4.2.3.1 Participant Screening (Appendix 1)

As stated in Chapter 3, section 3.2.3.1, a set of seven screening questions was administered to participants in order to assess their suitability and eligibility to take part in the study. Participants were instructed to answer these questions by stating whether the statement provided was “true” or “false.” Statements provided included the following: “I am 18 years old or over”, “I am female”, “I do not suffer from any form of skin condition”, “I do not suffer from any chronic pain condition”, “I am not pregnant”, “I have normal or corrected vision”. An additional statement was used for the participant to consent to take part in the study and they were instructed to agree if they wished to do so. If a participant responded by stating “false” to any of the seven statements listed above or did not click “I agree” to take part in the study, an “if then” function was applied. This function would prevent any ineligible participants from taking part and would direct this individual straight to the end of survey page, thanking them for their time.

To make certain participants in the healthy control group were not currently diagnosed or previously diagnosed with AN, participants were instructed to state their current AN diagnosis. Participants were asked the following ‘Please specify your current diagnosis of Anorexia Nervosa’ and have the choice of three options ‘Current diagnosis of Anorexia Nervosa, ‘Previous diagnosis of Anorexia Nervosa’ and No Diagnosis/history of Anorexia Nervosa’. This self-reported diagnosis was used to determine which group participants would be assigned to.

To categorise clinical patients into both the AN and RAN groups, those who answered having a current diagnosis of AN were placed into the AN group and those self-reporting a previous diagnosis of AN were assigned into the RAN group. AN patients were instructed to state the number of years they have had a formal diagnosis ‘If you have a current diagnosis of Anorexia Nervosa, for how many years have you had this?’. In addition, patients were asked to specify and declare whether they are currently receiving any form of treatment for their condition ‘Are you currently undergoing any treatment for Anorexia Nervosa (e.g., psychiatric treatments, SSRIs, tranquilizers, and or CBT)?’ Furthermore, patients in the RAN group were asked to specify the number of years they have been in remittance from AN: ‘If you have a previous diagnosis of Anorexia Nervosa, for how many years have you been recovered?.’ Patients in this group were not instructed to declare any previous treatment they have received in the past for this disorder. An “if then" functioned ensured that the questions which were specific for each AN populations were only displayed to the population they concerned i.e., patients reporting an RAN diagnosis were not asked about how many years they have had AN or any questions specific to treatment currently being received.

For both individuals with AN and RAN, these groups were required to state whether they had any neurological or psychiatric disorders such as ASD and to specify the disorder if they did. Three of our participants in the AN group self-reported that they had comorbidity with ASD. For the healthy control group, answering true to this question would automatically exclude them from the study.

4.2.3.2 Demographics Questionnaire (Appendix 2)

The demographic information obtained from participants was their age, gender, sex at birth, ethnicity, education level and relationship status. Participants also self-reported their height (cm/ft) and weight (Kg/lbs). Both combined were used to compute individual Body Mass Index (BMI). BMI was particularly important in the exclusion of AN participants i.e., those participants reporting a BMI greater than 18.5kg/m^2.

4.2.3.3 Multidimensional Assessment of Interoceptive Awareness (MAIA) Questionnaire (Appendix 3)

The Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling et al., 2012) is a 32-item questionnaire which assesses eight components of interoceptive awareness (see Chapter 2, section 2.3.3). In this study, the MAIA questionnaire was administered to investigate whether the interoceptive awareness i.e., Trusting, differed in individuals with AN, RAN and healthy controls and whether this was associated with pleasantness of social touch.

4.2.3.4 Eating Disorder Examination Questionnaire (EDE-Q) (Appendix 4)

The Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994) is a self-report questionnaire for the assessment of ED symptomatology (see Chapter 2, section 2.3.4). In this study, as stated by Carter et al. (2001) and Mond et al.

(2006) a cut off score of 4 or more was used to assign participants in the AN and RAN groups, and a cut off below 4 was used to classify participants into the healthy control group.

4.2.3.5 Touch Experiences and Attitudes Questionnaire (Appendix 7)

The Touch Experiences and Attitudes Questionnaire (TEAQ, Trotter et al., 2018b) is a questionnaire which measures experience and attitudes towards touch (see Chapter 2, section 2.3.7). This questionnaire assessed whether people with AN and RAN demonstrated a reduction in the experience of touch both currently from a partner, family, and friends and also during childhood and if this reflected a more negative attitude towards touch than healthy controls.

4.2.3.6 COVID-19 touch experiences and eating behaviour Questionnaire (Appendix 8)

This questionnaire consisted of twelve questions and was designed to measure touch experience and eating behaviour since the current COVID-19 pandemic. This questionnaire was administered to ensure touch deprivation during the Covid-19 pandemic did not influence touch pleasantness ratings at the time of data collection for all groups.

4.2.4 Procedure

4.2.4.1 General Procedure

The study was conducted using Qualtrics software, Version 60939 of the Qualtrics Research Suite. (Copyright © 2015 Qualtrics., Provo, UT, USA. http://www.qualtrics.com).

Participants from both the AN and RAN groups were contacted through Gatekeeper permission. All participants were provided with an invitation email which provided an overview of the study procedure and any inclusion and exclusion criteria. If participants were happy to take part in the study and met all criteria, they could click on the link provided in the invitation email. This link contained the participant information sheet, as well as a consent form and a pre-screening questionnaire to determine participants suitability to take part. If a participant was eligible and consent was obtained, they then viewed a series of affective touch videos and were asked to rate these videos according to their self-directed touch "How much would you like to be touched like that?" and other-directed touch : "How pleasant do you think that action was for the person being touched?." Both the videos and the questions were counterbalanced to avoid any order effects in the data.

After completing the affective touch rating task, participants then filled out the above-described questionnaires, which assessed eating disorder risk, body image concerns, body awareness, body misperceptions, experiences, and attitudes to touch, as well as social isolation and longing for touch since the COVID-19 pandemic in which the order these questionnaires were displayed was also counterbalanced.

Overall, the online study lasted approximately 35 minutes. Data collection began on 10th July 2020 and ended on 2nd December 2020. The same protocol was used as outlined in Chapter 3, section 3.2.4.1.

4.2.4.2 Statistical Analysis

All data were analysed using SPSS 26 (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.). After careful inspection of data, there was no violation of normality or sphericity.

Third-party pleasantness ratings of social touch were analysed by conducting a 4-way Mixed ANOVA with a between-subjects factor of Group (3 levels: AN, RAN and HCs) and within-subjects factors of velocity (3 levels: 0 cm/s, 5 cm/s and 30 cm/s), body sites (5 levels: Upper arm, ventral forearm, back, cheek and palm) and Task (2 levels: Other-directed touch and self-directed touch). All demographic information and scores for the self-reports are reported as the Mean (*M*) and Standard Deviation of the mean (*SD*). A significance threshold of $p<.05$ was used for each of the effects. All pairwise comparisons were assessed using Duncan's post-hoc test correction for multiple comparisons, which reduces the size of the critical difference depending on the number of steps separating the ordered means. This procedure is optimal for testing in the same design, effects that may have different sizes (Duncan, 1955; Dunnett, 1970; McHugh, 2011), as is expected in our case for the differences between AN, RAN and HCs participants, as well as for the size of the effects of the different within-subject variables (i.e., Self- vs. Other-directed touch effects).

Independent samples *t*-tests, with Bonferroni Correction were conducted to assess group differences for subscales of the EDE-Q, MAIA and TEAQ questionnaires, by examining significant differences in mean scores across each group. A significance threshold of $p<.05$ was used for each of the effects. For exploratory purposes, we considered all four factors of the EDE-Q, to also consider those factors which focus on the importance of and preoccupation with shape and weight, which the 3-factor model does not include.

In keeping with previous studies (Croy et al., 2016; Jönsson et al., 2017), and due to our findings suggesting that reduced pleasantness of self-directed touch was CT-optimal specific (please see Self-directed vs Other-directed affective touch ratings for full results), a Pleasant Touch Awareness (PTA) index was calculated as the difference in pleasantness ratings between CT-optimal (5 cm/s) and CT non-optimal stroking (30 cm/s), weighted by the average scores calculated separately for each participant and location (PTA= (pleasantness ratings at 5 cm/s − pleasantness ratings at 30 cm/s) / overall touch pleasantness). PTA measures the degree to which an individual prefers CT-optimal as opposed to CT non-optimal velocities (Croy et al., 2019), and it was used in the current study to compare preference for CT-optimal touch across the three groups (AN, RAN and HCs) and the two tasks. Furthermore, an Overall Touch Pleasantness (OTP index was calculated as the average across the CT-optimal velocity (5 cm/s) and CT-non optimal velocities (0 cm/s and 30 cm/s). This index was calculated separately for each group and task (Croy et al., 2016; Jönsson et al., 2017). OTP refers to the extent to which an individual finds touch pleasant, which is not CT-specific. Thus, in the current study we wanted to examine overall touch pleasantness amongst the three groups (AN, RAN and HCs) and self- vs. other-directed social touch.

For exploratory purposes, we performed a series of Multiple Linear Regression analyses to investigate the predictive role of TEAQ AIT and MAIA Trusting subscales on both PTA and OTA, across the three groups and tasks.

4.2.5 Results

4.2.5.1 Univariate Statistics

Table 4.2.5.1.1 reports means and standard deviations for the demographic and psychometric questionnaire subscales, which has been calculated separately for AN, RAN and HCs. The far-right column shows the output of pairwise comparisons between the three groups, which have been adjusted for multiple comparisons (Bonferroni-corrected). The three groups were matched for age. However, as expected, all groups differed regarding their self-reported BMI, with people with AN having a significantly lower BMI than HCs and individuals with RAN, and people with RAN had significantly lower (but still in the normal-weight range) BMI than HCs. Furthermore, as expected, individuals with AN had significantly higher EDE-Q global scores than people with RAN and HCs, whilst no difference was observed between individuals with RAN and HCs.

Between people with AN and HCs, there was a significant difference observed for the subscale MAIA Self-regulation, with HCs demonstrating higher ability to self-regulate distress when paying attention to inner body sensations, compared to people with AN. HCs had also significantly higher MAIA Trusting scores and thus reported greater experiences of their body as safe and trustworthy compared to both individuals with AN and RAN. No other group differences were observed for any other interoceptive facet, as measured by the MAIA.

For touch experiences and attitudes, HCs currently experience more family and friends touch and current intimate touch compared to people with AN. During childhood, HCs reported experiencing significantly more childhood touch compared to both individuals with AN and RAN. HCs also reported more positive attitudes towards self-care, and intimate touch compared to both people with AN and RAN and reported higher attitudes to unfamiliar touch compared to individuals with AN. Both individuals with AN and RAN did not differ in their current and previous touch experiences, and both demonstrated similar attitudes towards touch and self-care.

Table 4.2.5.1.1. Mean and standard deviation (in brackets) of demographics and self-report questionnaires scores for AN (*n* = *27*), RAN (*n* = *29*) and HCs (*n* = *35*).

	AN (*n=27*) M (SD)	RAN (*n=29*) M (SD)	HCs (*n=35*) M (SD)	AN vs. RAN *p*	AN vs HCs *p*	RAN vs. HCs *P*
Age (years)	25.56 (6.95)	27.31 (7.12)	27.20 (8.81)	ns	ns	ns
BMI (kg/cm^2)	17.58 (1.64)	22.59 (3.03)	24.77 (4.47)	<.001	<.001	.029
EDE-Q						
Restraint (max 6)	4.15 (1.54)	2.14 (1.93)	1.75 (1.68)	<.001	<.001	ns
Eating Concern (max 6)	3.30 (1.39)	1.83 (1.82)	1.13 (1.23)	.001	<.001	ns
Weight Concern (max 6)	4.16 (1.35)	2.96 (1.97)	2.45 (1.87)	.011	<.001	ns
Shape Concern (max 6)	4.16 (1.33)	3.07 (1.90)	2.77 (1.68)	.016	.001	ns
Global Score (max 6)	3.95 (1.24)	2.49 (1.77)	2.03 (1.47)	.001	<.001	ns
MAIA						
Noticing (max 5)	3.55 (1.01)	3.31 (1.06)	3.34 (1.07)	ns	ns	ns
Not Distracting (max 5)	2.58 (1.14)	2.41 (1.23)	2.80 (0.96)	ns	ns	ns
Not Worrying (max 5)	2.85 (1.29)	3.05 (1.16)	2.71 (0.99)	ns	ns	ns
Attention Regulation (max 5)	2.80 (0.96)	2.85 (1.20)	2.91 (0.98)	ns	ns	ns
Emotional Awareness (max 5)	3.24 (1.30)	3.32 (1.09)	3.46 (1.08)	ns	ns	ns
Self-regulation (max 5)	2.04 (1.25)	2.36 (1.38)	2.83 (1.14)	ns	.012	ns
Body Listening (max 5)	2.00 (1.31)	2.65 (1.24)	2.37 (1.27)	ns	ns	ns
Trusting (max 5)	1.46 (1.32)	2.25 (1.61)	3.14 (1.09)	ns	<.001	.011
TEAQ						
Friends and family touch (FFT; max 5)	2.68 (0.72)	2.99 (1.30)	3.51 (0.91)	ns	<.001	ns
Current intimate touch (CIT; max 5)	2.51 (0.89)	2.72 (0.97)	3.09 (0.90)	ns	.014	ns

Childhood touch (ChT; max 5)	3.09 (1.13)	3.02 (1.21)	3.85 (0.83)	ns	.003	.002
Attitude to self-care (ASC; max 5)	2.85 (1.07)	3.10 (0.87)	3.77 (0.78)	ns	<.001	.002
Attitude to intimate touch (AIT; max 5)	3.33 (1.02)	3.39 (1.08)	3.93 (0.85)	ns	0.14	.030
Attitude to unfamiliar touch (AUT; max 5)	2.30 (0.78)	2.36 (0.83)	2.78 (0.96)	ns	.040	ns

BMI Body Mass Index; *EDE-Q* Eating Disorder Examination Questionnaire; *MAIA* Multidimensional Assessment of Interoceptive Awareness; *TEAQ* Touch Experiences and Attitudes Questionnaire; *ns* Not Significant

Additional demographics such as ethnicity, relationship status and education level were also collected and are reported in Table 4.2.5.1.2. We conducted Chi-Square analysis between all 3 groups to investigate whether there were any differences in these demographics between groups. Importantly, there was no significant differences in ethnicity ($\chi^2_6 = 3.28$; $p = .773$), relationship status ($\chi^2_{16} = 13.18$; $p = .659$) and education level ($\chi^2_{10} = 5.33$; $p = .868$) between groups.

Table 4.2.5.1.2. Demographic characteristics of current AN (*n = 27*) recovered AN (*n = 29)* and HCs (*n = 35*), which have been analysed by Chi-square.

	AN *n* (%)	RAN *n* (%)	HCs *n* (%)
Ethnicity			
Caucasian	21 (77.8%)	24 (82.8%)	29 (82.9%)
Mixed	4 (14.8%)	2 (6.9%)	2 (5.7%)
Black	1 (3.7%)	2 (6.9%)	1 (2.9%)
Asian	1 (3.7%)	1 (3.4%)	3 (8.6%)
Relationship Status			
Single	11 (40.7%)	14 (48.3%)	14 (40%)
In a Relationship	10 (37%)	10 (34.5%)	10 (28.6%)

Engaged	1 (3.7%)	0 (0%)	1 (2.9%)
Married	3 (11.1%)	4 (13.8%)	8 (22.9%)
Separated	0 (0%)	0 (0%)	1 (2.9%)
Divorced	0 (0%)	1 (3.4%)	0 (0%)
Widowed	1 (3.7%)	0 (0%)	0 (0%)
Not Specified	0 (0%)	0 (0%)	1 (2.9%)
Prefer not to say	1 (3.7%)	0 (0%)	0 (0%)
Education Level			
High School	9 (33.3%)	6 (20.7%)	7 (20%)
College	4 (14.8%)	5 (17.2%)	8 (22.9%)
Foundation	3 (11.1%)	1 (3.4%)	2 (5.7%)
Bachelors	6 (22.2%)	9 (31.%)	11 (31.4%)
Masters	3 (11.1%)	5 (17.2%)	6 (17.1%)
Doctoral/Professional	2 (7.4%)	3 (10.3%)	1 (2.9%)
Treatment			
Medication	3 (11.1%)	-	-
Fluoxetine	1 (3.7%)	-	-
SSRI	2 (7.4%)	-	-
Bupropion	1 (3.7%)	-	-
Therapy	6 (22.2%)	-	-
CBT	1 (3.7%)	-	-
Online Therapy	1 (3.7%)	-	-
Therapy not specified	2 (7.4%)	-	-
Psychological/Psychiatric Treatment	2 (7.4%)	-	-
Day Patient Treatment	1 (3.7%)	-	-
Medication and Therapy	3 (11.1%)	-	-
No Treatment	12 (44.4%)	-	-
	AN	RAN	HCs

	M (SD)	M (SD)	M (SD)
Number of Years diagnosed	6.52 (8.62)	-	-
Number of Years Recovered	-	4.26 (3.60)	-

Table 4.2.5.1.3 demonstrates means and standard deviations for the Covid-19 subscales, which has been calculated separately for individuals with AN, RAN and HCs. The far-right column shows the output of pairwise comparisons between the three groups, which have been adjusted for multiple comparisons. HCs differed in their eating behaviours during the Covid-19 pandemic, reporting eating more than people with AN. Similarly, individuals with RAN also reported eating more during the Covid-19 pandemic than individuals with AN. During the pandemic, people with AN reported having done significantly more physical activity during the pandemic than individuals with RAN. All groups did not differ in any other Covid-19 subscale.

Table 4.2.5.1.3. Mean and standard deviation (in brackets) of demographics and Covid-19 subscale scores for AN (*n=27*), RAN (*n=29*) and HCs (*n=35*).

	AN (*n=27*) M (SD)	RAN (*n=29*) M (SD)	HCs (*n=35*) M (SD)	AN vs. RAN *p*	AN vs HCs *P*	RAN vs. HCs *P*
Given in Household (max 100)	15.56 (18.03)	24.89 (33.76)	15.88 (25.07)	*ns*	*ns*	*ns*
Received in Household (Max 100)	17.04 (24.64)	23.85 (31.52)	17.85 (26.87)	*ns*	*ns*	*ns*
Given to Stranger (Max 100)	67.38 (36.68)	66.86 (36.38)	82.38 (25.92)	*ns*	*ns*	*ns*
Received from Stranger (Max 100)	64.67 (38.40)	64.45 (38.40)	76.46 (29.76)	*ns*	*ns*	*ns*

Level of touch reduced (Max 100)	65.37 (28.02)	59.76 (32.17)	68.09 (24.54)	*ns*	*ns*	*ns*
Eating behaviours (Max 100)	31.35 (20.34)	50.59 (25.17)	60.26 (18.29)	*.003*	<*.001*	*ns*
Physical activity rate (Max 100)	54.00 (27.82)	35.69 (29.71)	44.77 (25.32)	*.021*	*ns*	*ns*
Social isolation (Max 100)	58.31 (34.12)	53.07 (32.34)	55.41 (32.40)	*ns*	*ns*	*ns*

AN Current Anorexia Nervosa; *RAN* Remitted Anorexia Nervosa; *HCs* Healthy Controls; *M* Mean; *SD* Standard Deviation; *ns* Not Significant

4.2.5.2 Self-directed vs Other-directed affective touch ratings

The Mixed ANOVA revealed a significant main effect of Body sites [F (4,352) = 19.10, p < .001, ηp^2 = .18], with the back being rated as most pleasant overall (all *ps* < .001). The upper arm, ventral forearm and palm were all rated as more pleasant than the cheek (all *ps* < .001). No other significant differences in pleasant ratings for the other body sites were observed (all *ps* > *.351).* There was also a significant main effect of velocity [F (2,176) = 11.99, p < .001, ηp^2 = .12], with CT-optimal touch (5 cm/s) rated as significantly more pleasant than touch applied at CT non-optimal velocities (0 cm/s and 30 cm/s) (all *ps* < .001). No significant differences were observed between the two CT non-optimal velocities (p = .682). There was a significant main effect of Task [F (1,88) = 67.57, p < .001, ηp^2 = .43], with overall touch being rated as more pleasant for other-directed touch compared to self-directed touch (p < .001). A significant main effect of Group was also observed [F (2,88) = 6.43, p = .002, ηp^2 = .13]. Overall, there were significant differences in pleasantness ratings between both HCs and individuals with AN (p = .022) and HCs and individuals with RAN (p = .002), with HCs providing higher overall pleasantness ratings compared to people with AN and RAN. No significant differences were observed in pleasantness ratings provided by individuals with AN and RAN (p = .301).

A significant 2-way interaction of body sites × velocity was revealed [F (8, 704) = 8.64, $p < .001$, $\eta p^2 = .09$] with a velocity of 5 cm/s to the ventral forearm being rated as significantly more pleasant than 30 cm/s to the ventral forearm ($p < .001$) and 0 cm/s to the ventral forearm ($p < .001$). Touch delivered at 5 cm/s to the cheek was rated as significantly more pleasant than touch delivered at both 30 cm/s ($p < .001$) and 0cm/s ($p < .001$). Also, touch delivered at 5 cm/s to the palm was rated as significantly more pleasant than that delivered at 30 cm/s ($p = .007$) and 0 cm/s ($p = .005$). All other body sites and velocities were not significant ($p > .224$).

Crucially, a 3-way interaction of velocity × task × group was also observed [F (4, 176) = 2.99, $p = .020$, $\eta p^2 = .06$; See Figure 4.2.5.2.1]. For self-directed touch, post-hoc comparisons of the three groups of AN, RAN and HCs at each level of velocity revealed that individuals with AN and RAN rated touch delivered at 5 cm/s significantly lower than HCs (all $p < .05$). No difference in pleasantness ratings was observed between individuals with AN and RAN for touch delivered at CT-optimal velocity ($p = .946$). A significant difference was also observed between pleasantness ratings provided by HCs and people with RAN for 30 cm/s ($p = .007$), with HCs providing higher preference ratings for 30 cm/s compared to individuals with RAN. There were no significant differences amongst the three groups in their ratings of 0 cm/s touch (all *ps* > .429). For the other-directed task, there was no significant differences between groups for any of the velocities (*all ps* > .05)

In summary, regardless of whether touch involved the self or another person, all groups demonstrated a preference for CT-optimal touch (5 cm/s) compared to CT-non optimal touch (0 cm/s and 30 cm/s). For all groups, touch evaluated for another person (other-directed touch) was perceived as more pleasant compared to when participants were asked to judge receiving the same touch to themselves (self-directed touch). Crucially, both individuals with AN and RAN demonstrated lower preference for self-directed touch when delivered at CT-optimal velocity (5 cm/s) than HCs.

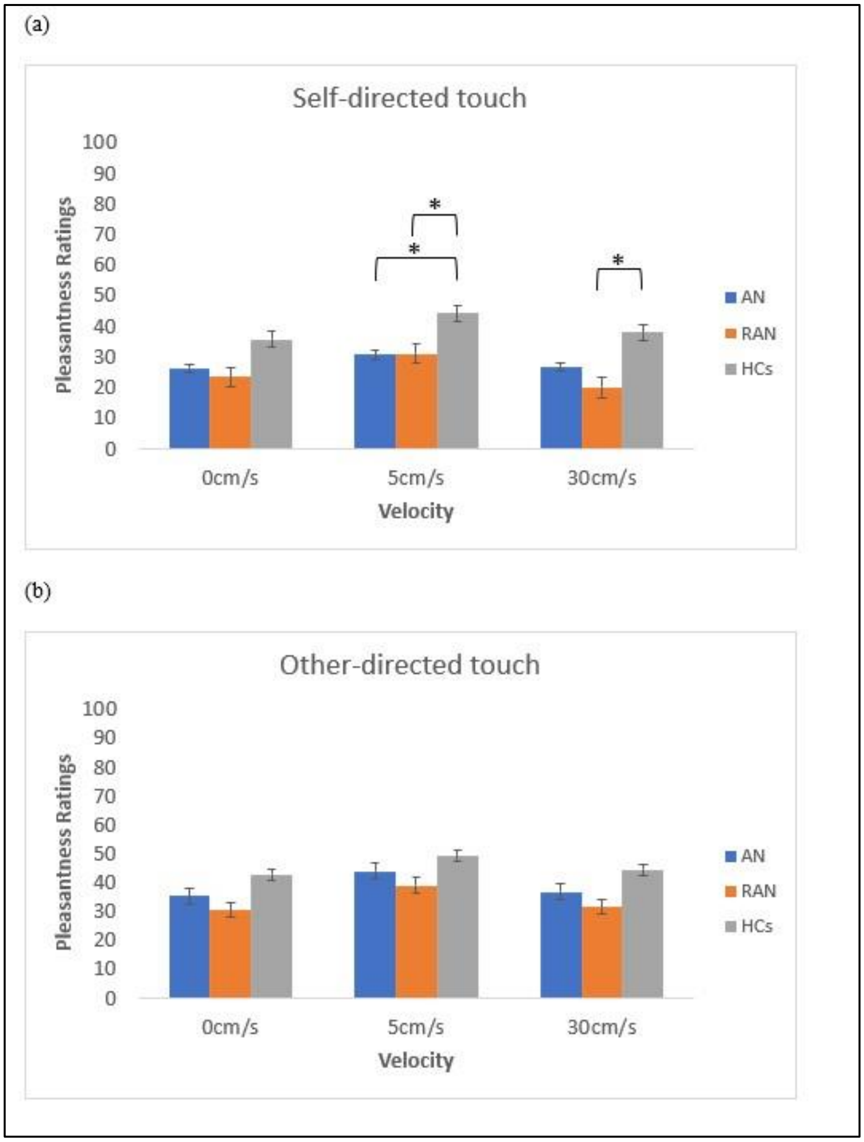

Figure 4.2.5.2.1. *Pleasantness ratings for each velocity, which have been collapsed across body sites, with each bar representing one of three groups (AN, RAN and HCs). Graphs are separated for each task: (a) self-directed touch and (b) other-directed touch.*

4.2.5.3 Pleasant touch awareness and overall touch perception related to attitudes in intimate touch and the trusting of one's own body

A series of exploratory Multiple Linear Regression analyses was performed to explore whether individual differences in experiences to intimate touch and of one's body as safe and trustworthy could predict individuals with AN, RAN and HCs' preference for

CT-optimal touch (PTA) or for overall touch (regardless of CT-Optimal specificity, OTP). Accordingly, TEAQ AIT and MAIA Trusting were included as predictors of PTA and OTP respectively for self- and other-directed touch.

For self-directed touch, a significant regression equation for the overall touch pleasantness for HCs [F (2,34) = 4.359, p = .021] and for individuals with AN [F (2,26) = 6.365, p = .006] was observed. For individuals with RAN, the regression equation was only marginally significant [F (2,28) = 3.219, p = .056]. Specifically, the TEAQ AIT was a significant predictor for overall touch preference for both HCs and people with AN, suggesting higher positive attitude towards intimate touch to predict higher pleasantness ratings to social touch (regardless of CT optimality of the stimulation) in both HCs and people with AN, but not in individuals with RAN (see Table 4.2.5.4.1). For other-directed touch, we did not find significant regression equations for the overall touch pleasantness for HCs [F (2,34) = .839, p = .441], AN [F (2,26) = 1.635, p = .216] or individuals with RAN [F (2,28) = .638, p = .537].

A separate Multiple Linear Regression analysis for each group was performed in order to investigate whether TEAQ AIT and MAIA Trusting would predict PTA for self-directed touch. No significant regression equations for either of the three groups (HCs [F (2,34) = .110, p = .896], individuals with AN [F (2,26) = .262, p = .772], RAN [F (2,28) = .715, p = .499]) was revealed. Similarly, no significant regression equations for PTA for other-directed touch in any of the three groups (HCs [F (2,34) = .432, p = .653], AN [F (2,26) = .356, p = .704] and RAN [F (2,28) = .089, p = .915], See Table 4.2.5.3.1) was observed.

Table 4.2.5.3.1. Unstandardized coefficients of the multiple linear regression model for MAIA Trusting and TEAQ Attitude to intimate touch (AIT) for both PTA and OTP separated for each group (AN, RAN and HCs) and task (self-directed and other-directed touch).

				B	**SE**	***β***	***t-value***	***p*-level**
HCs	**Self-directed**	**PTA**	MAIA_ Trusting	.040	.087	.082	.464	.646

			TEAQ_AIT	-.011	.111	-.018	-.102	.920
AN			MAIA_ Trusting	.063	.100	.129	.624	.538
			TEAQ_AIT	.030	.129	.048	.233	.818
RAN			MAIA_ Trusting	-.002	.117	-.003	-.014	.989
			TEAQ_AIT	-.188	.175	-.227	-1.072	.293
HCs	**Other-directed**		MAIA_ Trusting	.057	.062	.161	.918	.365
			TEAQ_AIT	-.017	.079	-.037	-.214	.832
AN			MAIA_ Trusting	.019	.066	.059	.290	.775
			TEAQ_AIT	.061	.085	.147	.718	.480
RAN			MAIA_ Trusting	.033	.078	.091	.422	.677
			TEAQ_AIT	-.020	.116	-.037	-.173	.864
HCs	**Self-directed**	**OTP**	MAIA_ Trusting	1.237	2.41	.080	.512	.612
			TEAQ_AIT	8.798	3.07	.450	2.862	.007*
AN			MAIA_ Trusting	3.135	2.04	.259	1.536	.138
			TEAQ_AIT	7.481	2.63	.479	2.843	.009*
RAN			MAIA_ Trusting	4.347	2.07	.407	2.092	.046
			TEAQ_AIT	1.218	3.10	.076	.392	.698
HCs	**Other-directed**		MAIA_ Trusting	.349	2.15	.028	.162	.872
			TEAQ_AIT	3.477	2.73	.219	1.270	.213
AN			MAIA_ Trusting	2.126	2.23	.186	.950	.352
			TEAQ_AIT	3.796	2.88	.257	1.315	.201
RAN			MAIA_ Trusting	2.345	2.21	.225	1.059	.299
			TEAQ_AIT	-.341	3.31	-.022	-.103	.919

Notes: *AN* Current Anorexia Nervosa, *RAN* Remitted Anorexia Nervosa, *HCs* Healthy Controls, *PTA* Pleasant Touch Awareness, *OTP* Overall Touch Pleasantness, *MAIA* Multidimensional Assessment of Interoceptive Awareness, *TEAQ* Touch Experiences and Attitudes Questionnaire, *AIT* Attitudes to Intimate Touch. *Indicates $p < 0.01$

4.2.5 Pleasantness of touch and the influences of the Covid-19 pandemic

For exploratory purposes, a series of Pearson's correlations with a Bonferroni correction amongst all self-report subscales to assess any association between Covid-19 with the PTA and OTP indices, was performed separately for each group.

4.2.5.1 Pleasant Touch Awareness Correlations

For exploratory purposes, the association with touch avoidance and social isolation due to Covid-19 with pleasant touch awareness index (PTA) was conducted for each group and calculated separately per task.

For self-directed touch, Covid-19 subscales were not significantly associated with PTA for HCs (*all rs* > -.153, *ps* > .222). For people with AN, PTA was positively associated with a greater reduction in touch received in household (*r* = .537, *p*= .004) and more touch wanting during the Covid-19 pandemic (*r* = .388, *p* = .046). For individuals with RAN, PTA was negatively associated with levels of social isolation (*r* = -.481, *p* = .010).

For other-directed touch, Covid-19 subscales were not significantly associated with PTA for HCs (*all rs* > -.299, *ps* > .086). For individuals with AN, PTA was positively associated with greater Covid-19 eating behaviours (*r* = .441, *p* = .024). For people with RAN, Covid-19 subscales were not significantly associated with PTA (*all rs* > -.125, *ps* > .070).

To summarise, pleasantness of CT-optimal touch involving the self and touch to another was largely influenced by Covid-19 for the AN group. Particularly, greater reduction in touch in household and touch wanting were associated with the pleasantness of touch for this group. Social isolation was a predictor of touch pleasantness for CT-optimal touch for individuals with RAN only. Covid-19 did not have an influence on touch pleasantness for CT-optimal touch for the HCs.

4.2.5.2 Overall Touch Pleasantness Correlations

Moreover, for exploratory purposes, the association with touch avoidance and social isolation due to Covid-19 with overall touch pleasantness (OTP) was performed for each group and calculated separately per task.

For self-directed touch, Covid-19 subscales were not significantly associated with OTP for HCs (*all rs* > -.009, *ps* > .291), individuals with AN (*all rs* > -.009, *ps* > .291) and RAN (*all rs* > -.229, *ps* > .056).

For other-directed touch, Covid-19 subscales were not significantly associated with OTP for HCs (*all rs* > -.282, *ps* > .107) and also for people with AN (*all rs* > -.192, *ps* > .079). For individuals with RAN, greater levels of touch wanting was positively associated with OTP (r = .376, p = .048).

To summarise, Covid-19 was not associated with overall touch pleasantness for any of the groups. For both people with AN and HCs, Covid-19 did not influence overall pleasantness judgements involving touch for another person. Only greater levels of touch wanting predicted overall touch pleasantness for people with RAN but no other group.

4.2.6 Discussion

This was the first study to investigate whether women with a diagnosis of AN and RAN differed in vicarious ratings of self vs. other-directed social touch, delivered at CT-optimal vs. CT non-optimal velocities, compared to healthy controls with no current or previous AN diagnosis. We considered interoceptive awareness and attitude to intimate touch as factors that could predict pleasantness ratings for social touch, given that these are key contributors in the aetiology and development of EDs (Beilharz et al., 2019; Kaye et al., 2009; Nandrino et al., 2012; Strigo et al., 2013). We also took into consideration any impact Covid-19 may have had on pleasantness ratings, given the global pandemic at the time of data collection.

The results show that, as unexpected and regardless of task, both individuals with AN and RAN rated CT-optimal touch as more pleasant than non-optimal touch. Although the case, both women with AN and RAN demonstrated significantly lower pleasantness ratings for CT-optimal touch compared to HCs. This finding is in line with Crucianelli et al. (2016) who identified that people with AN rated CT-optimal touch as less pleasant than healthy controls, which was not evident for CT-non optimal velocities. Additionally, this finding also supports research by Davidovic et al. (2018), whereby individuals with a current diagnosis of AN rated touch as less pleasant than HCs. Yet, this finding contradicts Crucianelli et al. (2021) as they found that a reduction in tactile pleasantness was not CT-specific. A probable explanation for this finding is that atypical responses to affective touch occurred consequent to an error in bottom-up processing i.e., in the perception and sensation of touch, which as proposed by Crucianelli et al. (2016) be due to a dysfunctional CT afferent system. This finding is specifically more apparent for self-directed touch.

As predicted, both patient groups displayed atypical affective touch pleasantness ratings for self-directed touch, regardless of touch velocity, compared to healthy controls. This finding supports Crucianelli et al. (2021) who found that women recovered from AN evaluated affective touch as less pleasant than healthy controls. As proposed by Crucianelli et al. (2021), women with AN have interoceptive deficits, such as reduced tactile pleasure. In support, Zucker et al. (2013) found that women with AN, have an enhanced negative sensitivity to sensory experiences such as touch (Zucker et al., 2013). Thus, a potential explanation concerning atypical responses to affective touch when delivered to the self could be consequent to this negative sensitivity to touch (Zucker et al., 2013) and anxiety and discomfort towards touch (Arcelus et al., 2014). Thus, as proposed by Crucianelli et al. (2021), these findings from the current study suggest that a reduction in touch pleasantness is not a consequence of a symptom of anorexia such as starvation, but a trait present even post recovery. This could explain individuals with AN' difficulties in maintaining intimate relationships with a partner or close relationships with family and friends (Evans & Wertheim, 1998). The more severe symptoms of AN such as greater body image disturbances, the more they find intimate touch to be discomforting from a partner or loved one (Thomas et al., 2004). This could therefore explain why both individuals with AN and RAN rated touch as less pleasant than healthy controls, as they engage in lower levels of touch (Sailer & Ackerley, 2017). Nevertheless, as this study is the first to assess vicarious ratings of observed touch, it is difficult to draw solid comparisons from previous literature, as these all involved direct experience of touch for the self only.

Conflicting to what was expected, the experience of one's own body as safe and trustworthy (MAIA trusting) was not as a key predictor in the ratings of CT-optimal and non-optimal touch for any of the three groups. This was surprising given that Brown et al. (2020) reported the MAIA trusting subscale to be essential in interoceptive and ED symptoms. A possible suggestion could be that other factors of interoception might be key in predicting the perception of social touch in AN. A study conducted by Crucianelli et al. (2021) revealed that interoceptive sensibility scores, were associated with perceived pleasantness of CT-optimal touch in people with AN. Therefore, future studies assessing factors which predict perception of social touch in AN are required in order to understand which facets of interoceptive awareness are predictors of pleasantness of touch in AN. This would allow for a more solid overview of the mechanisms which contribute towards vicarious experiences of social touch in AN.

Surprisingly, no group differences were observed for third party ratings of pleasantness of touch for another. It was expected that group differences would be observed given AN' atypical responses to touch to self (Crucianelli et al., 2021), which were also identified in the current study. Prior research has suggested that individuals with AN have an impaired theory of mind, which has been found to manifest even after recovery (de Sampaio et al., 2013; Gál et al., 2011; Hamatani et al., 2016; Konstantopoulos et al., 2020; Russell et al., 2009; Tchanturia et al., 2018; Zucker et al., 2007) and involves the decoding of affective stimuli (Bora & Köse, 2016) both with self and other perspectives (Cooper & Mohr, 2012; Ruby & Decety, 2003). It was expected that individuals with AN would use their own touch experiences and evaluation of touch, in order to interpret how another individual would evaluate touch. Thus, as people with AN typically rate social touch as unpleasant, this evaluation would be less pleasant compared to how neurotypical populations would perceive touch for another. However, both AN and RAN groups did not rate CT touch as less pleasant compared to healthy controls for other-directed touch. Instead, as previously found, no differences was revealed been women with AN and healthy controls regarding perspective taking when evaluating touch for another (Adenzato et al., 2012; Bora & Köse, 2016; Calvo et al., 2014; Medina-Pradas et al., 2012). A possible explanation could be consequent to learned experiences i.e., individual with AN have learned that although they perceive touch to themselves as less pleasant regardless of velocity, they are aware that other individuals do find that touch pleasant, and so when asked to make a judgement, they use this inference rather than their own experiences. In doing so, they may have enhanced the development of their theory of mind, which is a process which enhances based on an individual's experience of that specific interaction. Individuals with AN may be exposed to touch on a regular basis which may not be self-specific. They may observe how others respond to interpersonal touch and use this learned experience when making judgments of touch for others (Korkmaz, 2011). Another possible explanation is that, as found previously (Adenzato, Todisco, & Ardito, 2012; Bora & Köse, 2016; Calvo et al., 2014; Medina-Pradas, Navarro, Álvarez-Moya, Grau, & Obiols, 2012), AN have an intact theory of mind.

Whilst this was the first investigation to evaluate third-party ratings of social touch in both women with AN and RAN, several limitations were detected. Firstly, self-reported AN and RAN diagnosis may have resulted in concerns with variability of individuals in these clinical populations. Additionally, self-reported diagnosis of not having an eating disorder may put the healthy control group at risk of including individuals undiagnosed with AN. In order to try and control this, we had strict BMI categories to ensure that participants met this diagnostic criterion to be categorised as current or remitted and also as a healthy control. Also, as suggested by Wolk et al. (2015), the EDE-Q is a good measure to use in order to assess AN diagnosis, as this is a good replacement for an eating disorder examination interview (Fairburn, Cooper, & O'Connor, 1993, 2008) which was the questionnaire used in the current study. Nevertheless, these factors may not have caused issues in the current sample, as given that the study was online, participants were more likely to be open about their diagnosis due to anonymity. Also, participants' responses to questions ensured that those who were not deemed "fit" to take part could not continue with the investigation. Also given the current Covid-19 pandemic, it was difficult for communicative reasons and limited resources to get clinical interviews in place. However, for future studies it will be useful to use clinical interviews in order to ascertain clinical diagnosis from a qualified clinician (Sysko et al., 2015). Furthermore, it would be beneficial to have a real touch condition in addition to imagined self-directed touch, as in Crucianelli et al. (2021). This would allow for a comparison to understand whether these populations have atypical responses to both actual and imagined touch. Nevertheless, this was not possible at the time of the investigation due to lockdown consequent to the Covid-19 pandemic.

Although the current study controlled for various facets of touch experience and metacognitive interoception which may impact pleasantness of touch, other variables such as touch avoidance and exposure may have accounted for these results. In support, a study conducted by Sailer and Ackerley (2019) found that those participants with low levels of touch exposure, measured through the Social Touch Questionnaire (STQ; Wilhelm, Kochar, Roth, & Gross, 2001) demonstrated atypical touch responses, as touch was not velocity specific. In addition, mood may have had a negative impact on social touch responses, even though participants were asked to state if they had any neurological or psychiatric conditions. Other measurements for anhedonia such as the Fawcett-Clark Pleasure Scale (FCPS; Fawcett, Clark, Scheftner, & Gibbons, 1983) or the Snaith-Hamilton Pleasure Scale (SHAPS; Snaith et al., 1995) to assess participants' mood at the time of testing, would have been useful. Those participants demonstrating a significantly low mood at the time of testing could have been excluded from the study, as anhedonia, a trait of depression in which an individual has a diminished capacity to feel pleasure, can result in an individual experiencing negative attitudes towards social touch (Triscoli, Croy, & Sailer, 2019). This would be important to take into consideration in future studies given than these characteristics manifest post-recovery from AN, which could account for lower pleasantness towards touch Crucianelli et al. (2021).

Moreover, another variable which may greatly influence individual differences in third-party vicarious ratings of social touch is individual levels of empathy, which impacts participants' performances for embodiment and during vicarious experiences (Kaplan & Iacoboni, 2006; Minio-Paluello et al., 2009; Rueda, Fernández-Berrocal, & Baron-Cohen, 2014). In support, Peled-Avron et al. (2016) found that EEG responses to social touch images was modulated by levels of empathy. Those participants who were more empathetic, rated social touch as more pleasant and in conjunction had higher mu suppression, compared to those less empathetic. Therefore, future studies involving social interactions such as third-party ratings of touch, should consider including an empathy measure to ensure this factor is not significantly affecting the results, as observing someone receiving touch is modulated by individual differences in empathy. Also, previous research has found that individuals with AN typically have lower levels of empathy compared to people with RAN and HCs (Konstantakpooulos et al., 2020; Morris et al., 2014).

Additionally, given the findings from the current investigation emphasising an impairment in self-directed touch, future studies should combine neurophysiological techniques such as Transcranial Magnetic Stimulation (TMS), to understand the neural underpinnings of affective touch, to examine if atypical responses to social touch is specific to top-down influences, rather than bottom-up influences. Previous research has found an association with atypical affective touch and a dysregulated ability to predict and cognitively represent and regulate the physiological state of one's body and alexithymia in AN (Crucianelli et al., 2021). Also, to understand the brain regions facilitating the abnormalities of touch arising because of the mismatch between anticipation and experience of touch (Crucianelli et al., 2021). Therefore, study four investigated the neural underpinnings of vicarious social touch to better understand the regions impaired in self-directed vs. other-directed touch and the association with ED symptomatology (see Chapter 5).

4.2.6.1 Conclusions

Overall, findings suggest that although women with an eating disorder have atypical responses to affective touch compared to healthy controls, unexpectedly, these women still demonstrate preference for CT-optimal touch. Additionally, third-party ratings of touch pleasantness for another individual does not differ regardless of eating disorder diagnosis, however both women with RAN and AN rated affective touch as less pleasant compared to healthy controls when touch involved the self. Thus, altered responses to affective touch in women with AN and RAN appear to be self-specific and are intact when making judgements of touch for someone else. This could be due to a learning mechanism i.e., although people with AN and RAN do not explicitly find touch themselves pleasant, they have learned that the touch they are viewing would be pleasant for another individual (but not for themselves). Furthermore, ED traits, interoceptive awareness and social touch experiences are associated with overall touch pleasantness particularly for women with and recovered from AN. In the future, it will be useful to use clinical interviews to formal diagnose individuals with AN and RAN, as self-report measures are not always accurate. Factors such as mood, self-esteem, or empathy which may have impacted pleasantness ratings, which are important for touch processing in individuals with EDs, should be accounted for in further investigations. Also, it will be useful to combine psychophysiological measures to also capture unconscious and complex emotional responses to touch. Furthermore, as the current study demonstrated that atypical responses to self-directed touch persist post-recovery, treatment interventions should focus on this to prevent frequent relapsing, through a form of mirror therapy such as the repetitive exposure of oneself in a mirror performing a specific action (Hilbert, Tuschen-Caffier, & Vögele, 2002). Self-touch to different regions in a mirror could be incorporated into this therapy to improve body awareness and negative body perception (Griffen, Naumann, & Hildebrandt, 2018).

Chapter 5

Topography and relationship-specific social touching in individuals at risk for body image

Based on the findings from study 2, in which individuals with AN and RAN displayed atypical responses to self-directed social touch, we wanted to understand whether this is dependent upon the social context, specifically the relationship of the touch provider. This was in order to understand if self-directed social touch responses in people with AN is mediated by the relationship of the touch giver. This is particularly important given that previous research of Suvilehto et al. (2015) revealed that the regions individuals are able to touch and found to be pleasant to be touched, is more restrictive the more distant the emotional bond between the touch giver and receiver (Suvilehto et al., 2015, 2019). This is particularly important to understand in relation to self-directed touch for individuals with AN, whether all touch regardless of the touch relationship is evaluated as unpleasant or whether this is specific for more distant individuals such as strangers and clinicians.

Furthermore, this is the first study to assess the use of a virtual mobile phone application to assess soothing and unpleasantness of imagined social touch to various body regions from a loved one compared to an acquaintance, in individuals with high and low levels of body image disturbances. Little research has addressed social touch impairments in individuals with body image disturbances, specifically AN (Bellard et al., 2022; Bischoff-Grethe et al., 2018; Davidovic et al., 2018; Crucianelli et al., 2016, 2021) or subthreshold body image disturbances (Carey et al., 2019, 2021, Cazzato et al., 2021). These populations tend to display negative responses to receiving touch from both familiar and unfamiliar individuals (Zucker et al., 2013). In order to measure this, participants (both high and low levels of BIDs) interacted with a 3D avatar and using a heatmap scale, indicated the body regions they found to be soothing or unpleasant to be touched from a loved one and an acquaintance.

Furthermore, this is also the first study to assess atypical responses to social touch and body image disturbances across 13 different body regions, as opposed to focusing on the arm and palm (Bischoff-Grethe et al., 2018; Davidovic et al., 2018; Crucianelli et al., 2016, 2021).

5.1 Introduction

Social touch is a method of communication exchanged between two people and is a form of a non-verbal approach to communicate emotions and affections (Brauer, Xiao, Poulain, Friederici, & Schirmer, 2016; Cascio, Moore, & McGlone, 2019; Jönsson et al., 2018; Björnsdotter, Morrison, & Olausson, 2010; Von Mohr, Kirsch, & Fotopoulou, 2017). As outlined by the Social Touch hypothesis, gentle touch is also important for development and bonding during early childhood (Morrison et al., 2010; Vallbo et al., 1999). The pleasantness and comfort of gentle social touch is believed to be facilitated by the C-tactile pleasant touch pathway in which unmyelinated, low-threshold mechanosensory C-tactile afferents (CTs) are activated in response to slow, gentle touch to the hairy part of the skin and processed in the Insula Cortex, a region involved in the affective dimension of touch (McGlone et al., 2014; Gordon et al., 2013). In addition, touch induces various positive physiological and psychological changes to the touch receiver such as a reduction in blood pressure, reduced anxiety, and a decrease in heart rate (Drescher et al., 1980; Grewen et al., 2003; Olson & Sneed, 1995). This degree of touch exchange between two individuals is greater in relationships relating to a partner or first-degree relatives (Sorokowska et al., 2021). The more touch that is shared between two individuals, the stronger the bond formed between them both (Gallace & Spence, 2010; Russo et al., 2020). Nevertheless, the body sites an individual finds pleasant and comfortable to be touched, is dependent upon the relationship shared between them and the touch provider. The greater the distance in relationship, the less body areas are pleasant to be touched. Body areas classified as intimate regions, are restricted only to touch from a partner, whereas strangers are limited to touch to the hands only (Jolink et al., 2022; Suvilehto et al., 2015).

Overall, slow, gentle touch has largely been found to be pleasant and comforting in healthy populations (Ackerley et al., 2014; Croy et al., 2016; Löken et al., 2011). Nevertheless, individuals suffering from various psychiatric conditions such as posttraumatic stress disorder (Strauss et al., 2019) and anorexia nervosa (AN, Crucianelli et al., 2016, 2021; Bischoff-Grethe et al., 2018; Davidovic et al., 2018; Tagini et al., 2023; Frost-Karlsson et al., 2022), do not experience the rewarding benefits of touch. This is more evident in AN, a severe psychiatric condition characterised by body size overestimations, distortions, and disturbances such as Dysmorphic concerns (Beilharz, Phillipou, Castle, Jenkins, Cistullo, & Rossell, 2019; Cazzato et al., 2016; Urgesi et al., 2014). As a result of this, patients develop an intense fear of gaining weight and engage in atypical eating habits i.e., restricting their food and calorie intake and consequently patients with this disorder are abnormally underweight (APA, 2013). Also, individuals with AN demonstrate an impaired interoceptive awareness and cannot accurately interpret internal bodily sensations such as hunger or their heartbeat (Kaye et al., 2009; Khalsa et al., 2015; Kerr et al., 2016; Monteleone & Maj, 2013; Oberndorfer et al., 2013; Perez, Coley, Crandall, Di Lorenzo, & Bravender, 2013; Strigo et al., 2013). Interoceptive deficits are believed to be key in the emergence and maintenance of AN (Kaye et al., 2009; Nandrino et al., 2012; Strigo et al., 2013) and is linked to a disruption in the Insula Cortex, a region involved in interoceptive processing of internal bodily sensations (Craig, 2002; Kerr et al., 2016; Kirsch et al., 2020). This disruption to the functioning of the Insula Cortex could explain why individuals with AN struggle in linking internal bodily sensations with hedonic feelings (Nunn et al., 2008).

Importantly, research focusing on atypical responses to social touch in AN is restricted, with only a small number of studies to date (Bischoff-Grethe et al., 2018; Davidovic et al., 2018; Crucianelli et al., 2016, 2021) and only a small number of studies examining social touch impairments in individuals at risk of AN (Carey et al., 2019, 2021, Cazzato et al., 2021). Research has revealed that individuals with AN rate interpersonal gentle touch as less pleasant, due to an altered perception of tactile stimuli (Keizer et al., 2011; Frost-Karlsson et al., 2022). In addition, people with AN also display atypical social touch perception which results in higher levels of touch avoidance and withdrawal from social situations (Cardi et al., 2018; Kerr-Gaffney et al., 2018; Patel et al., 2016). For example, Crucianelli et al. (2016) found that individuals with AN evaluated affective touch as less pleasant than healthy controls who rated touch as very pleasant. This study offers support that people with AN possess an atypical perception of social touch. To further support, Davidovic et al. (2018) revealed that compared to healthy controls, people with AN also displayed a reduction in pleasantness to affective touch. Nevertheless, although the case, fMRI data revealed that these patients displayed no significant differences in Insula Cortex functioning before and after the recipient of touch, result found similar with healthy control individuals. On the contrary, Bischoff-Grethe et al. (2018) discovered that both individuals with recovered AN and healthy controls displayed no significant difference in the anticipation or perception of touch and demonstrated similar pleasantness responses and no differences in brain activation. An additional study by Crucianelli et al. (2021) revealed that both people with current and recovered AN anticipated and evaluated affective touch as less pleasant than healthy controls. Furthermore, Study 2 (Bellard et al., 2022) revealed that social touch impairments occur in relation to self-directed touch as opposed to other-directed touch, which is not specific to CT-optimal touch. All studies above provide a foundation for the association of social affective touch and eating disorders, specifically AN. Interestingly, a recent study by Tagini et al. (2023) provides the first evidence of an association between lifetime experiences of affective contact and the appreciation of affective touch (Beltrán et al., 2020). This study reported that the more people with AN are familiar with affective touch in early, primary relationships, the more they appreciate real touch when delivered by an (unfamiliar) experimenter, as compared to a non-affective touch (Tagini et al., 2023). Nevertheless, these studies do not resemble the affective, gentle touch an individual would receive in a real life, instead all touch is provided through a brush and/or by a stranger (unfamiliar researcher), which may account for negative responses towards touch. As outlined previously, the type of touch, the body areas allowed to be touched and the affective response is largely impacted by the closeness of the touch giver and receiver (Gazzola et al., 2012; Jones & Yarbrough, 1985; Nummenmaa et al., 2016; Strauss et al., 2020; Suvilehto et al., 2015, 2019, 2021; Willis & Briggs, 1992). Overall, additional research is essential to understand if atypical responses to social touch in AN is relationship specific and dependent upon the body regions these individuals receive touch, when provided in a real-life scenario.

5.1.1 The Current Study

The current investigation aimed to assess the imagined perception of soothing and unpleasantness responses to social touch in real life affective scenarios in individuals with high and low levels of BIDs. Social touch is an experience which strengthens emotional bonds between two individuals. These bonds are not only between caregiver and child, but also romantic bonds and friendships. The type of touch shared between two individuals, is largely dependent upon the strength of the emotional bond (Suvilehto et al., 2015, 2019; Willis & Briggs, 1992). The area of the body that specific individuals are allowed to touch, is dependent upon the relationship shared and the identity of the touch provider, with romantic partners being capable to touch private areas such as genitals, with touch across the whole body being evaluated as pleasant. In contrast, strangers are restricted to areas such as the hands and this touch is largely evaluated as being unpleasant (Gazzola et al., 2012; Jones & Yarbrough, 1985; Nummenmaa et al., 2016; Strauss et al., 2020; Suvilehto et al., 2015, 2019, 2021). In particular, Suvilehto et al. (2015) instructed participants to specify using bodies of human silhouettes, the body sites individuals of varying relationships such as partner, parent and stranger, the regions these individuals were accepted to touch them. It was revealed that those individuals classified as having closer emotional bonds such as a partner or parent, were able to touch more body regions compared to when touch was given from a stranger, which was restricted to the hands and upper torso only. Partners where the only individuals able to touch 'taboo' regions such as the genitals and buttocks. Those closer to the touch receiver were able to touch more regions and these regions were classified as being pleasant to be touched (Suvilehto et al., 2015). In order to measure soothing and unpleasant responses to social touch from a loved one and an acquaintance in individuals high and low levels of BIDs, 'the Virtual Touch Toolkit' (Najm et al., 2022) was employed. Individuals were instructed to interact with a 3D avatar of a male or female silhouette and using heatmaps to indicate regions of the body, they find soothing or unpleasant to be touched from a loved one compared to an acquaintance

In addition, individual differences in body image concerns and dysmorphic concerns and the contribution towards pleasantness of touch to different body regions from a loved one and an acquaintance was also measured. Recent findings have revealed that a reduction in preference for touch from a stranger is associated with lower levels of emotional awareness and higher dysmorphic concerns (Cazzato et al., 2021). Moreover, given that individuals with AN display an enhanced negative sensitivity to sensory experiences i.e., touch and avoid touch from familiar and unfamiliar individuals (Zucker et al., 2013), it was hypothesised that individuals with high levels of BIDs will display lower soothing ratings to touch compared to low levels of BIDs, who will display no differences in ratings for touch from a loved one and an acquaintance. Furthermore, it is anticipated that for the high levels of BIDs group, greater levels of unpleasantness to touch, regardless of whether this is from a loved one or an acquaintance, will be associated with higher levels of dysmorphic concerns and greater interoceptive deficits.

5.2 Methods

5.2.1 Participants

A total sample of 69 participants (22 males and 47 females) (M_{age}=28.19yrs, SD=11.27) were recruited and preselected based on the median EDI-3 EDCR score (Median= 39, high levels of BIDs group: M = 62.91, SD = 16.18 & low levels of BIDs group: M = 18.74, SD = 10.35), which is a self-report questionnaire administered to assess levels of disordered eating and risk for an eating disorder (Garner, 2004). Based on this score, participants were assigned to either high levels of BIDs or low levels of BIDs group. (See Table 5.3.1 below for a breakdown of EDI-3 scores and demographic information for each of the two groups). The total sample size for this study was calculated through a G* Power 3.0.10 power analysis, which indicated a minimum sample of 60 participants was required for a medium effect (f = .25) with 95% power, using a Mixed ANOVA with alpha at .05 (two tailed).

Based on the EDI-3 EDCR score, a total of thirty-four high levels of BIDs aged 20-66 (M_{age}= 30.68yrs, SD = 14.55), consisting of 12 males and 22 females was recruited for this group. An additional thirty-five low levels of BIDs aged 18-41 (M_{age}= 25.77, SD = 6.01), comprising of 10 who were male and 25 who were female.

Participants for both the high and low level of BIDs were recruited from the UK and also in Germany through various platforms such as social media, recruitment agencies, external contacts, and the University SONA participant recruitment scheme. For the participants collected in Germany, in order to maintain consistency, this research was constructed and collected in English language. It was vital that for this study, all participants did not possess any psychiatric or neurological disorders. Also, that they did not have a current diagnosis or previous eating disorder formal diagnosis. All participants had normal or corrected vision and did not have any form of skin or chronic pain conditions such as eczema or fibromyalgia. Also, it was vital that none of the participants recruited were pregnant.

All participants gave full implied consent to participate and at the end of the study were provided with a full debrief and overview of what the study was about. As a gesture for their time, participants were provided shopping vouchers as a compensation for their time. Level 4 BSc Psychology students received SONA credits. The study was carried out in accordance with the Helsinki declaration of ethical standards. The study protocol was approved by Liverpool John Moores University (LJMU)'s University Research Ethics Committee (UREC, protocol: 21/PSY/013).

5.2.2 Measures

5.2.2.1 The Virtual Touch Toolkit

The Virtual Touch Toolkit is a newly established mobile application, in the Beta testing phase at present. This application enables participants to download to their mobile and freely interact through various exercises (Najm et al., 2022). This application has the possibility to be used as a research tool to virtually investigate social touch with healthy controls and those with body image disturbances. The application comprises of various touch exercises, which are categorised into four main types: Mindfulness, Stress Control, Bodily Awareness and Touch Training. The exercises include an array of interactional interfaces such as sound, 3D Models, and text-based instructions. The data that is collected from this application includes a participant's current emotional state, the performance from the exercise and the emotional state post completion of the exercise. The Virtual touch toolkit creates a virtual environment in which individuals are able to experience touch, in particular individuals with body image disturbances such as AN, without the added stress of receiving actual touch. In addition, the self-touch exercises help with the encouragement of rhythmic skin stroking and potentially the brain releasing oxytocin when being instructed to engaged in self-hugging. Also, social touch exercises allow for the understanding as to whether individuals with body image disturbances demonstrate atypical responses to social touch in individuals external from their family environment, such as a clinician. This can be assessed virtually on various body areas, without these individuals being subject to distress from actually receiving touch from various individuals to different body parts (Najm et al., 2022). In future, this application has the potential to be used with individuals with body image disorders such as Anorexia Nervosa (Gentsch et al., 2016) to investigate atypical social touch responses across various social situations such as from a clinician or loved one.

For the current study, participants were provided with detailed instructions of how to download the application for both Android and iOS phone and how to navigate to the exercise “My body in your hands”. Participants were asked to create a user account by selecting their gender, age, and were asked to select either a male or female silhouette which represents the gender they identify with. To ensure confidentiality, no names or identifiable information was asked, instead participants entered a unique participant code which matched their app data with their questionnaire data.

Participants interacted with the exercise titled: “My body in your hands”. For this exercise, participants interacted with a 3D virtual ‘human’ model and were instructed, using brush tool and a colour scale (blue = soothing (+100) to red = unpleasant (-100)), to specify which body areas they evaluate as being soothing or unpleasant to be touched from a loved one compared to an acquaintance. For this exercise, participants imagined being touched to various regions from a loved one and an acquaintance and were instructed to demonstrate what regions they would find soothing and unpleasant to be touched (for an illustration of the exercise instructions, see Figure 5.2.2.1.1). To keep consistent with a loved one, participants were asked to imagine being touched from a partner, as ‘loved one’ could also be from a parent, child, or friend. Individual heatmaps for both touch providers were created i.e., one for a loved one and a separate for an acquaintance. Prior to submitting their responses, participants were presented with a final step where they could see both avatars for loved one vs. acquaintance displayed together, to ensure they were happy with their responses, and they were correct for each condition. To ensure as much accuracy as possible, participants could manipulate the size of the brush tool, which prevented any cross contamination of colour to different regions. Overall, this task took participants approximately 10 minutes to complete (for visualisation see Figure 5.2.2.1.1).

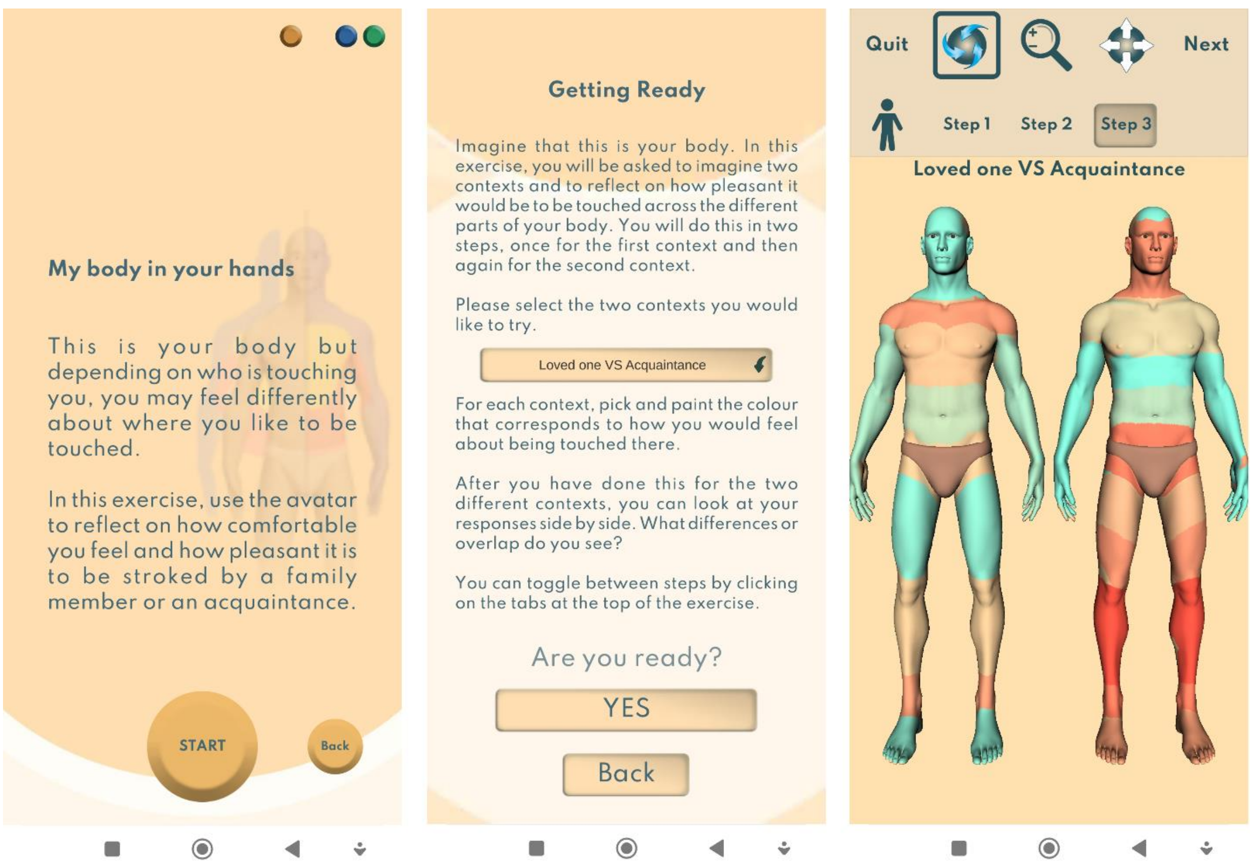

Figure 5.2.2.1.1. *“My body in your hands” exercise. Image of virtual ‘human’ models participants used to determine soothing/unpleasantness of touch for specific body areas, from a loved one vs an acquaintance. This image represents a male silhouette, with the*

option of selecting a female silhouette. Image credit: Prof Merle Fairhurst, The Virtual Touch Toolkit (https://www.unibw.de/virtualtouch-en/virtual-touch-toolkit).

5.2.3 Self-report Questionnaires

5.2.3.1 Demographics Questionnaire (Appendix 2)

Demographic information taken from participants included their age, gender, ethnicity, date of birth, relationship status, sexual orientation, and education level. Participants were asked to self-report their actual height (in cm/ft) and body weight (kg/lbs) for calculating their BMIs. Participants who took part in the lab-based data collection has their weight measured using a calibrated bioimpedance digital scale (OMRON BF511) and a stadiometer for their height.

5.2.3.2 The Eating Disorder Inventory-3 Questionnaire (Appendix 5)

The Eating Disorder Inventory-3 (EDI-3) (Garner, 2004) is a 91 item self-report questionnaire assessing eating disorder symptomatology. This questionnaire assesses 12 subscales, 3 of which assess eating disorder symptomatology (see Chapter 2, section 2.3.5). In this study, this questionnaire was administered to examine participants' risk of EDs (high vs. low levels of BIDs). The Eating Disorder Risk Composite (EDRC) score was used to assign a participant to one of two groups: high BIDs vs. low BIDs risk. The median split of the EDRC was used. The subscale 'Interoceptive Deficits' was used as a measure of emotional awareness and to assess a participant's ability to understand their internal bodily and emotional states (Garner, 2004).

5.2.3.3 Dysmorphic Concern Questionnaire (Appendix 6)

The Dysmorphic Concern Questionnaire (DCQ) (Oosthuizen et al.,1998) is a short questionnaire used to measure an individual's concern towards their physical appearance (see Chapter 2, section 2.3.6). This measure was used to determine whether higher levels of dysmorphic concern, was associated with more unpleasantness to touch regardless of the touch giver.

5.2.4 Procedure

5.2.4.1 General Procedure

This study was conducted online and also in the lab and used Qualtrics software, Version 60,939 of the Qualtrics Research Suite (Copyright © 2015 Qualtrics., Provo, UT, USA. http://www.qualtrics.com). Due to Covid-19 restrictions, we decided it was necessary to move from online to lab-based data collection, this was due to the lack of engagement from participants. Also, during the beginning of the study, restrictions were still in place meaning that participants could not take part to face-to-face research, which was another reasoning behind the original online data collection.

Both versions of the study used the same weblink to keep it consistent. Participants were emailed with an invitation which comprised of a brief overview of the study. Those that took part online were provided with a link to the study and were instructed to click the hyperlink if they were happy to participate. All participants received an electronic version of the information sheet and were asked to provide consent to take part. After providing consent to take part, participants were given a unique code generated randomly through Qualtrics and asked to take note of this. Participants used this unique code on all questionnaires and on the task. This ensured that their Qualtrics questionnaire responses could be linked to their task data collected on the Virtual touch app. Participants then were given a detailed instruction of how to download the app, how to create their user profile using their unique code and where the task was located on the app. Proceeding from downloading the app, participants completed the “my body in your hands” exercise by completing Heatmaps demonstrating the regions of the body the find soothing and unpleasant to be touched from a loved one compared to an acquaintance using a colour scale (blue= soothing (+100) to red= unpleasant (-100)) and brush tool. After completion of the task, participants filled out a series of questionnaires through Qualtrics. These questionnaires measured body image disturbances, body image concerns, body image misperception and body awareness through the EDI-3 (Garner, 2004) and DCQ (Oosthuizen et al.,1998). These questionnaires were fully counterbalanced for each participant.

Overall, this study took both online and lab participation 35 minutes to complete. This study began on 3rd August 2021 and ended on 31st March 2022.

5.2.4.2 Data Handling and Statistical Analysis

Data were analysed using IBM SPSS 26 (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp). Inspection of model residuals indicated data were normally distributed. Assumptions of sphericity were not violated. Based on findings from Suvilehto et al. (2015), we categorised the body zones; Abdomen, Groin, Buttocks, Upper Leg and Face as intimate regions. We grouped social regions as the Head, Hands, Upper Arm, Lower Arm, Lower Legs, Feet, Back and Shoulders. As in Suvilehto (2019), we also computed a 'touchability index' (TI) which is the proportion of coloured pixels within the body outline for each touch area maps (TAM).

First, independent samples *t*-tests, with Bonferroni Correction were conducted to assess group differences for subscales of the EDI-3 and DCQ questionnaires, by examining significant differences in mean scores across each group.

We conducted an additional 3-way Mixed ANOVA with a between-subjects factor of Group (2 levels: high levels of BIDs and low levels of BIDs) and within-subjects factors of Relationship (2 levels: loved one and acquaintance) and Body Zone (Region of Interest: ROI, 13 levels). As in Suvilehto (2019), we also computed a 'touchability index' (TI) which is the proportion of coloured pixels within the body outline for each touch area maps (TAM). This was calculated to test the effects of relationship on touchable body area in the two groups.

Soothing/unpleasantness of social touch was also analysed by conducting a preliminary 3-way Mixed ANOVA with a between-subjects factor of Group (2 levels: high levels of BIDs and low levels of BIDs) and within-subjects factors of Relationship

(2 levels: loved one and acquaintance) and Body Zone (2 levels: intimate and social regions). This analysis demonstrated that low and high levels of BIDs groups both provided higher soothing touch ratings for social body regions as opposed to intimate body regions [F (1, 67) = 120.946, $p < 0.001$, $\eta p2 = 0.064$]. This was also evident when considering relationship, higher soothing ratings were provided when touch was delivered from a loved one than for an acquaintance in which this touch was rated as unpleasant [F (1, 67) = 139.868, $p < 0.001$, $\eta p^2 = 0.068$]. The 2-way interaction of relationship × body zone was also significant [F (1, 67) = 22.549, $p < 0.001$, $\eta p^2 = 0.025$]. This 2-way interaction was followed by a significant 3-way interaction of group × relationship × body zone [F (1, 67) = 5.874, $p = 0.018$, $\eta p^2 = 0.08$]. This 3-way interaction demonstrated different relationship × body zone effects according to the levels of BIDs group (high and low levels of BIDs). As this 3-way interaction was observed in our preliminary analysis, our main analysis aimed to examine whether the significant interaction of relationship × body zone was determined by levels of BIDs. Two separate 2-way repeated measures ANOVAs with Relationship (2 levels: loved one vs. acquaintance) and Body Zone (2 levels: intimate vs. social regions) as within-subject variables, was conducted separately for each group (high vs. low levels of BIDs).

The association between TI for intimate and social regions touched form a loved one vs. an acquaintance with DCQ and emotional awareness (Interoceptive Deficits, EDI-3) was explored through a series of multiple linear regressions. These data were reported as Mean (M) and standard error of the mean (S.E.M).

A significance threshold of $p<.05$ was used as the significance threshold for each of the effects. All pairwise comparisons were assessed using Duncan's post-hoc test correction for multiple comparisons.

5.2.5 Results

Table 5.2.5.1 presents the means and standard deviations for participant demographics and questionnaire subscales, which have been calculated separately for high levels of BIDs and low levels of BIDs groups. The third column shows the result of pairwise comparisons between the two groups (Bonferroni corrected for multiple comparisons). Both groups were matched for age. As expected, both groups differed regarding EDI-3 subscale scores, with the high levels of BIDs group having significantly higher drive for thinness, greater body dissatisfaction, emotional dysregulation and interoceptive deficits, lower self-esteem, higher interpersonal alienation, ascetism (abstinence from sensual pleasure), maturity fears, more feelings of personal alienation and higher interpersonal insecurity compared to the low levels of BIDs group. As anticipated, both groups differed significantly in their EDRC score, with the low levels of BIDs group being representative of a healthy population (score < 18) and the high levels of BIDs group demonstrating a clinical group score, with the mean score greater than the cut-off point (score > 32). Surprisingly, both groups did not differ in their levels of dysmorphic concerns as measured by the DCQ, with both groups displaying similarly high levels of dysmorphic concerns (see Table 5.2.5.1).

Table 5.2.5.1. Mean and standard deviation (in brackets) of demographics and self-report questionnaires scores for the high levels of BIDs group (*n= 35*) compared to the low levels of BIDs group (*n=34*).

	High BIDs (*n= 34*) M (SD)	Low BIDs (*n= 35*) M (SD)	High vs. low BIDs *P*
Age	30.68 (14.55)	25.77 (6.01)	.07
EDI-3			
Drive for Thinness	16.62 (6.05)	4.11 (4.29)	<.001
Body Dissatisfaction	25.21 (9.15)	10.06 (6.76)	<.001
Bulimia	21.09 (8.82)	4.57 (4.84)	<.001
Low self esteem	15.32 (3.78)	4.40 (5.17)	<.001
Interpersonal alienation	14.21 (6.58)	6.20 (4.28)	<.001
Emotional Dysregulation	16.32 (9.32)	5.14 (6.09)	<.001
Perfectionism	10.71 (5.06)	9.80 (5.02)	ns

Ascetism	15.82 (7.84)	5.20 (4.67)	<.001
Maturity Fear	15.15 (6.22)	9.46 (7.26)	<.001
Personal Alienation	16.68 (6.90)	5.83 (4.42)	<.001
Interpersonal Insecurity	14.97 (5.86)	7.71 (4.91)	<.001
Interoceptive Deficit	19.21 (10.60)	6.83 (6.15)	<.001
Composite Risk	62.91 (16.18)	18.74 (10.35)	<.001
DCQ	14.32 (5.43)	14.80 (6.34)	ns

EDI-3 Eating Disorder Inventory 3; *DCQ* Dysmorphic Concern Questionnaire; *ns* Not Significant

5.2.5.1 Imagined social touch: Region-of-interest analysis for individual body sites

As shown in Figure 5.2.5.1.1, both high and low BIDs groups rated touch from a loved one as soothing regardless of the body zone. Body zones such as the abdomen and groin were rated as slightly less soothing compared to body zones such as the arm and hands.

For an acquaintance, the abdomen was rated as the most unpleasant for both high levels of BIDs and low level of BIDs groups. Similarly, both groups rated the groin, upper leg, buttocks, shoulders/back, feet, legs, face, and head as unpleasant. However, groups differed in their ratings for the upper arm, lower arm, and hands, with the high levels of BIDs group rating these regions as significantly more soothing compared to the low levels of BIDs group, who demonstrated more unpleasantness of touch from an acquaintance to these regions, except for the hands (see table 5.2.5.1.1 for the mean soothing/unpleasantness ratings for all 13 body regions for a loved one and an acquaintance for high and low levels of BIDs).

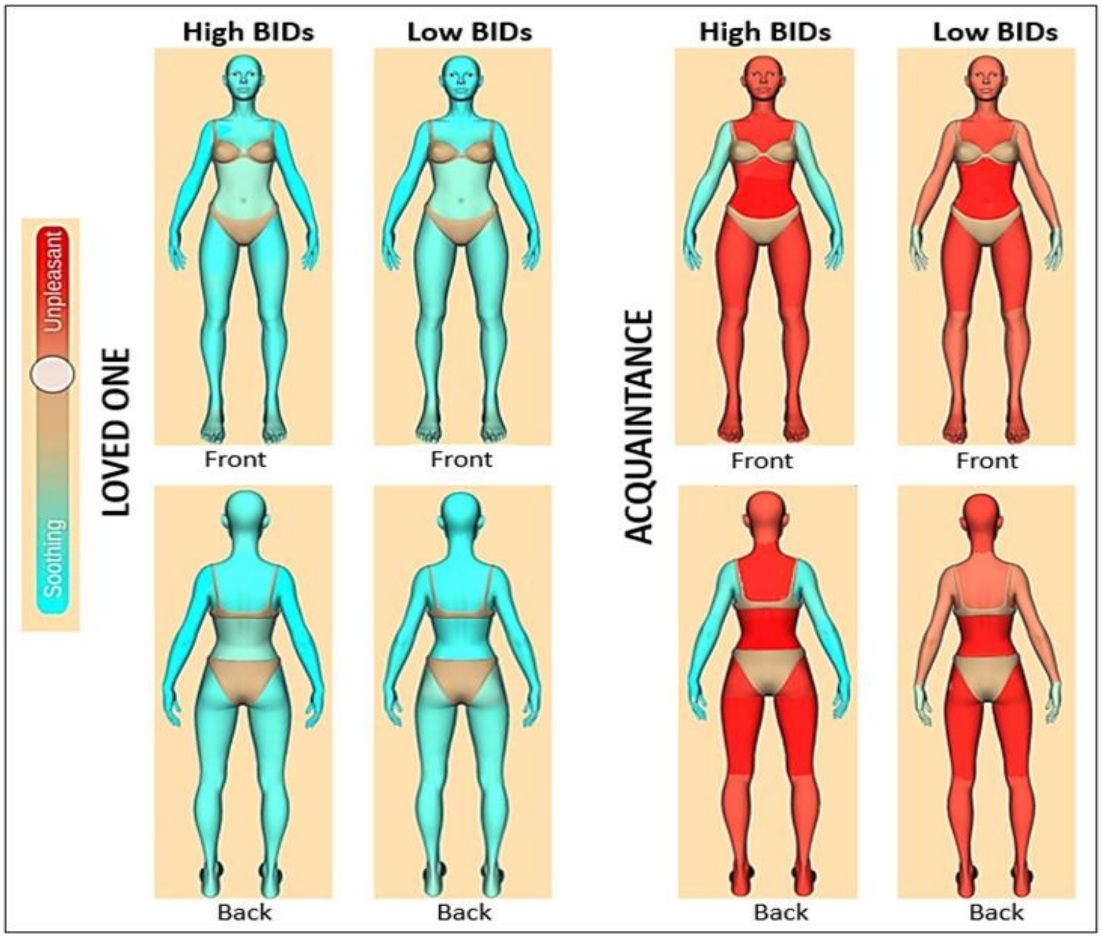

Figure 5.2.5.1.1. *Demonstrates individual body ratings for each body zone, which has been separated for both relationship (loved one vs. acquaintance) and for group (High levels of BIDs and Low levels of BIDs). Image shows both front and back of a 3D avatar silhouette. Red on the scale indicates unpleasant responses to touch and blue demonstrates soothing responses to touch.*

Table 5.2.5.1.1 Mean (standard error of the mean in brackets) of soothing/unpleasant ratings for the implicit task for the two groups of Low (n=35) and high levels of BIDs (n=34). Scores depict ratings of imagined touchability for 13 bodily regions, according to the social relationship between the touch receiver and the touch giver (loved one vs. an acquaintance).

	Low levels of BIDs (n = 35)	High levels of BIDS (n =34)

	Loved one	Acquaintance	Loved one	Acquaintance
Buttock	12.45 (±8.56)	−50.96 (±6.72)	26.12 (±9.71)	−50.6 (±7.48)
Face	35.85 (±6.37)	−38.58 (±5.96)	40.55 (±7.49)	−25.44 (±8.76)
Feet	9.94 (±8.43)	−41.06 (±5.69)	18.05 (±8.72)	−36.07 (±7.06)
Groin	0.57 (±10)	−58.78 (±5.58)	29.95 (±10.26)	−54.09 (±6.96)
Hand	57.70 (±6.05)	1.33 (±6.67)	55.16 (±6.05)	30.1 (±8.01)
Lower arm	52.27 (±6.15)	−0.62 (±7.23)	55.02 (±6.17)	22.06 (±8.24)
Lower leg	29.72 (±7.31)	−38.40 (±7.08)	34.48 (±7.71)	−36.1 (±8.25)
Shoulders & upper back	47.88 (±6.35)	−17.29 (±6.13)	41.62 (±7.86)	−17.25 (±8.9)
Shoulders & upper torso	23.92 (±8.22)	−46.03 (±6.04)	39.53 (±7.91)	−44.89 (±7.47)
Torso	15.94 (±8.45)	−62.07 (±5.46)	21.23 (±10.72)	−55.54 (±7.5)
Upper arm	48.38 (±5.49)	−1.40 (±5.83)	49.53 (±6.72)	10.59 (±8.6)
Upper leg	22.54 (±7.56)	−51.28 (±5.95)	35.15 (±8.27)	−50.71 (±7.03)
Head	43.09 (±5.90)	−37.06 (±5.53)	37.75 (±6.84)	−19.84 (±7.58)

The 3-way mixed ANOVA revealed a significant main effect of Body Zone [F (12, 804) = 53.427, $p < .001$, $\eta p^2 = .44$]. Touch to the buttocks was rated as significantly more unpleasant than the face, hands, lower arm, lower leg, upper back, upper torso, upper arm, and head (*all ps* < .03). Touch to the face was rated as significantly more soothing than the feet, groin, upper torso, abdomen, and upper leg (*all ps* < .012) and significantly less soothing than the hands, lower arm, upper back, and upper arm (*all ps* < .007). Touch to the feet was rated as significantly less unpleasant than the groin ($p = .04$) and abdomen ($p = .05$) and significantly more unpleasant than touch to the hands, lower arm, lower leg, upper back, upper arm, and head (*all ps* < .017). Touch to the groin was rated as significantly more unpleasant than the hands, lower arm, lower leg, upper back, upper torso, upper arm, upper leg, and head (*all ps* < .022). Touch to the hands was rated as significantly more soothing than touch to the lower leg, upper back, upper torso, abdomen, upper arm, upper leg, and head (*all ps* < .02). Touch to the lower arm was rated as significantly more soothing than touch to the lower leg, upper back, upper torso, abdomen, upper leg, and head (*all ps* < .001). Touch to the lower leg was rated as significantly less soothing than touch to the upper back, upper arm, and head (*all ps* < .032). Touch to the lower leg was rated as significantly more soothing than touch to the upper torso, and upper leg (*all ps* $< .033$). Touch to the upper back was rated as significantly more soothing than touch to the head, upper torso, abdomen, and upper leg (*all ps* $< .040$) and significantly less soothing than touch to the upper arm ($p = .001$). Touch to the upper torso was rated as significantly less unpleasant than touch to the abdomen and upper leg (*all ps* $< .001$) and more unpleasant than touch to the upper arm and head (*all ps* $< .001$). Touch to the abdomen was rated as significantly more unpleasant than touch to the upper arm, upper leg, and head (*all ps* $< .028$). Touch to the upper arm was rated as significantly more soothing than the upper leg, and head (*all ps* $< .001$). Touch to the upper leg was rated as significantly more unpleasant than to the head ($p < .001$).

There was also a significant main effect of Relationship [F (1,67) = 139.402, $p < .001$, $\eta p^2 = .68$], with touch from a loved one being rated as significantly more soothing than touch from an acquaintance, which was rated as unpleasant ($p < .001$).

A significant main 2-way interaction was observed between Body Zone × Relationship [F (12,804) = 10.311, $p < .001$, $\eta p^2 = .13$]. Buttocks (acquaintance) was rated as significantly more unpleasant than buttocks (loved one), which was rated as soothing ($p < .001$). Face (acquaintance) was rated as significantly more unpleasant than face (loved one), which was rated as soothing ($p < .001$). Feet (acquaintance) was rated as significantly more unpleasant than feet (loved one), which was rated as soothing ($p < .001$). Groin (acquaintance) was rated as significantly more unpleasant than groin (loved one) ($p < .001$), which was rated as soothing. Hands (acquaintance) was rated as significantly less soothing than hands (loved one) ($p < .001$). Lower arm (acquaintance) was rated as significantly less soothing than Lower arm (loved one) ($p < .001$). Lower leg (acquaintance) was rated as significantly more unpleasant than lower leg (loved one) ($p < .001$), which was rated as soothing. Shoulders/upper back (acquaintance) was rated as significantly more unpleasant than shoulders/upper back (loved one) ($p < .001$), which was rated as soothing. Shoulders/upper torso (acquaintance) was rated as significantly more unpleasant than shoulders/upper torso (loved one) ($p < .001$), which was rated as soothing. Torso (acquaintance) was rated as significantly more unpleasant than Torso (loved one) ($p < .001$), which was rated as soothing. Upper arm (acquaintance) was rated as significantly more unpleasant than upper arm (loved one) ($p < .001$), which was rated as soothing. Upper leg (acquaintance) was rated as significantly more unpleasant than upper leg (loved one) ($p < .001$), which was rated as soothing. Head (acquaintance) was rated as significantly more unpleasant than head (loved one) ($p < .001$), which was rated as soothing.

Crucially, a significant 3-way interaction of body zone × relationship × group was also observed [F (12,804) = 3.593, $p < .001$, $\eta p^2 = .05$, see Figure 5.2.5.1.2]. Independent t-tests were used to follow up this interaction and revealed a significant difference between high BIDs and low levels of BIDs in ratings for touch from a loved one to the groin ($p = .04$), with high levels of BIDs rated touch as more soothing compared to low levels of BIDs. Touch to the hands from an acquaintance was rated as significantly more soothing for high levels of BIDs compared to low levels of BIDs ($p = .007$). Touch to the lower arm from an acquaintance was rated as significantly more soothing for high levels of BIDs compared to low levels of BIDs, who rated this touch as slightly unpleasant (p= .04). We did not observe a significant main effect of group [F (1,67) = 1.555, $p = .217$, $\eta p^2 = .02$]. No significant 2-way interaction was observed between Relationship x Group [F (1,67) = 0.047, $p = .828$, $\eta p^2 = .00$], and Body Zone x Group [F (12,804) = 0.832, p= .617, $\eta p^2 = .01$].

In summary, significant differences for touch ratings from a loved one compared to an acquaintance, between high levels of BIDs and low levels of BIDs, occurred for touch to the groin from a loved one, with high levels of BIDs findings this touch slightly more soothing than low levels of BIDs. Touch to the hand and were rated as soothing for both high and low levels of BIDs. However, touch to the lower arm were rated as soothing for high and slightly unpleasant for low levels of BIDs. These findings are in line with previous research in that touch to more taboo areas such as the groin (genitals) is only soothing when given from a close loved one (Suvilehto et al., 2015). The only touch evaluated as soothing from an acquaintance was for the hands and arms only. These are regions previous research has found are the areas strangers are restricted to touching (Suvilehto et al., 2015).

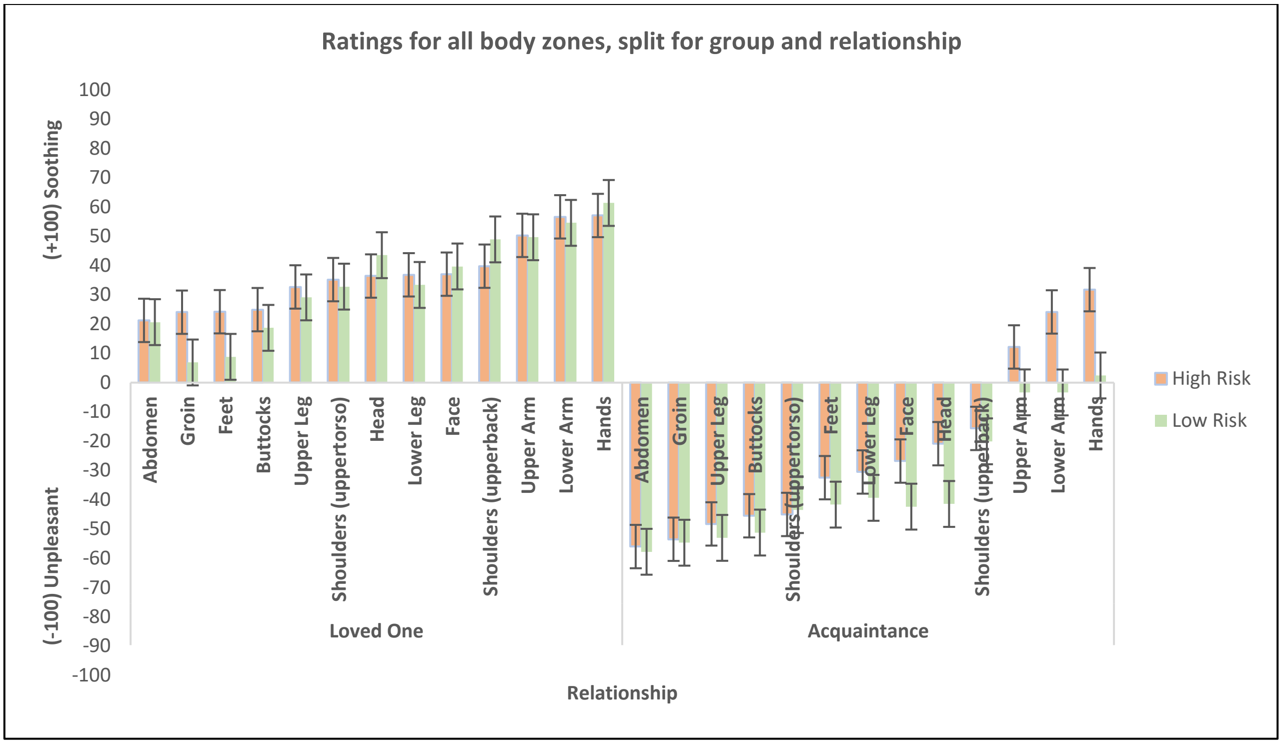

Figure 5.2.5.1.2. *Demonstrates 3 way-interaction between relationship (loved one vs. acquaintance), ROI (13 individual body zones) and group (high levels of BIDs vs. low levels of BIDs).*

5.2.5.2 Imagined social touch: Intimate vs. Social Regions

5.2.5.2.1 Low levels of BIDs group

The 2-way ANOVA for the low levels of BIDs group revealed a significant main effect of Body Zone [F (1,34) = 56.557, $p <$ .001, $\eta p^2 = .625$]. Social body zones were rated as significantly more soothing than intimate body zones which instead were rated unpleasant (8.27 ± 2.89 vs. -17.43 ± 4.14, $p < .001$). There was also a significant main effect of relationship [F (1,34) = 71.262, $p <$. 001, $\eta p^2 = .677$], with touch from a loved one being rated as significantly more soothing than touch received from an acquaintance (28.29 ± 5.62 vs. -37.45 ± 4.28, $p < .001$). However, the 2-way interaction of body zone × relationship was not significant [F (1,34) = 3.199, $p = .083$, $\eta p^2 = .086$]. This finding therefore implies that low levels of BIDs group did not differ in soothing ratings for touch given to both intimate and social body regions and this was not influenced by the social relationship shared with the touch provider (see figure 5.2.5.2.1b)

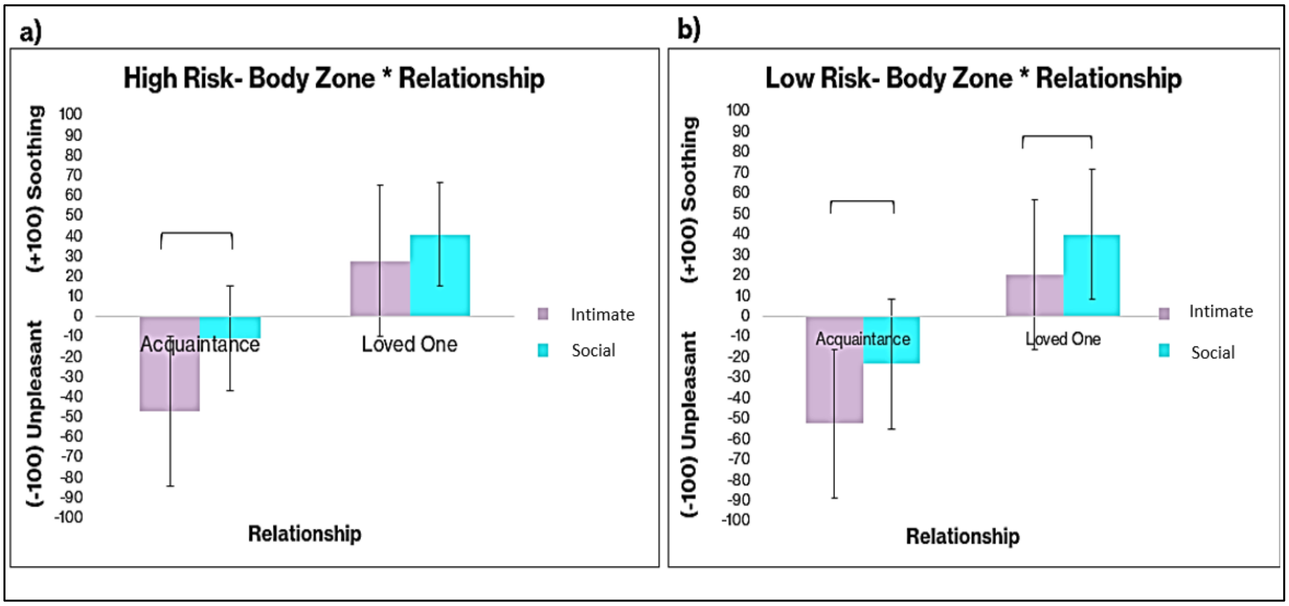

Figure 5.2.5.2.1. *Soothing/unpleasantness ratings for each body zone (Intimate vs. social) separated for each relationship (acquaintance vs. loved one). Graphs are separated for each group (a) High levels of BIDs group and (b) Low levels of BIDs group.*

5.2.5.2.2 High levels of BIDs group

The 2-way ANOVA for the high levels of BIDs group revealed a significant main effect of Body Zone [F (1,33) = 67.346, $p < .001$, $\eta p^2 = .671$]. Social body zones were rated as significantly more soothing than intimate body zones, which instead were rated as significantly more unpleasant (14.98 ± 5.38 vs. − 8.34 ± 5.84, $p < .001$). There was also a significant main effect of Relationship [F (1,33) = 68.648, $p <$. 001, $\eta p^2 = .675$], with touch from a loved one being rated as significantly more soothing than touch received from an acquaintance (36 ± 7.16 vs. − 29.35 ± 6.23, $p < .001$). A significant 2-way interaction of body zone × relationship [F (1,33) = 22.103, $p < .001$, $\eta p^2 = .401$] was also revealed. Post-hoc comparisons revealed that participants displaying high levels of BIDs rated touch to intimate regions from a loved one as significantly more soothing than touch received by an acquaintance, which in turn was rated as unpleasant (30.60 ± 8.26 vs. -47.28 ± 6.62, $p < .001$). Touch to social body regions was rated as significantly more soothing when received from a loved one as compared to touch received by an acquaintance, which in turn was rated as unpleasant (41.39 ± 6.41 vs. -11.43 ± 6.49, $p < .001$; see figure 5.2.5.2.1a)

In summary, overall imagined touch was perceived as the most soothing when the touch provider was of a closer bond i.e., a loved one, compared to a more distant emotional relationship, such as an acquaintance. Touch to intimate regions was rated as most unpleasant compared to touch to social regions. Nevertheless, as shown by the 2-way interaction, social relationship was reliant upon the body site that the touch provided to. Therefore, this results implies that the relationship of the touch provider to the receiver is important in establishing bodily maps of socially acceptable touch in high levels of BIDs.

5.2.5.3 Multiple Regression Analysis: Interoceptive deficit, dysmorphic concerns, and soothing/unpleasantness to touch

We performed a series of multiple regression analysis to explore if participants responses to imagined touch delivered at intimate/social body sites and depending on the relationship with the touch provider (loved one vs. acquaintance) could be predicted by individual differences in dysmorphic concerns (DCQ) and levels of emotional awareness (interoceptive deficit- EDI-3). This was done by combining both groups and also separately for high levels of BIDs and low levels of BIDs.

The linear multiple regression analysis calculated to predict TI for intimate body regions touched by a loved one from symptoms of dysmorphic concerns and emotional awareness for the whole sample was significant [F (2,66) = 3.456, p = .037, R^2 = .308], with Emotional Awareness emerging as the only significant predictor (p = .023). For the high levels of BIDs group, the linear multiple regression analysis calculated to predict TI for intimate body regions touched by a loved one from symptoms of dysmorphic concerns and emotional awareness was significant [F (2,31) = 4.199, p = .024, R^2 = .462], with

Emotional Awareness emerging as the only marginally significant predictor. The regression equation for social body regions touched by a loved one only approached significance, with Emotional Awareness (Interoceptive Deficit – EDI-3) being a marginally significant predictor [F (2,31) = 3.148, p = .057, R^2 = .411; see table 5.2.5.3.1]. Similarly, no significant regression equations were found for any of the TI conditions in the whole sample or separately for the low levels of BIDs group. Therefore, for high levels of BIDs, interoceptive awareness difficulties correlated with greater soothing ratings for intimate and social body regions, when this touch is provided from a loved one.

Table 5.2.5.3.1 Unstandardised coefficients from the linear multiple regression models of dysmorphic concerns and emotional awareness predictors of the touchability at intimate and social bodily regions when touched by a loved one versus an acquaintance, respectively.

	Touchability									
	low levels of BIDs Group (n =35)					**high levels of BIDs Group (n=34)**				
	Sensitive Bodily Regions touched by a Loved one									
	B	SE	*β*	*t*	*p*	B	SE	*β*	*T*	*p*
Interoceptive Deficit (EDI-3)	-0.01	0.19	-0.07	- 0.06	0.95	0.31	0.16	1.43	1.96	0.06
DCQ	0.06	0.19	0.39	0.32	0.75	-0.30	0.16	-2.70	-1.80	0.07
	Insensitive Bodily Regions touched by a Loved one									
	B	SE	*β*	*t*	*p*	B	SE	*β*	*T*	*P*
Interoceptive Deficit (EDI-3)	0.09	0.18	0.45	0.50	0.62	0.32	0.16	1.11	1.92	0.06
DCQ	0.13	0.18	0.64	0.74	0.47	-0.23	0.16	-1.57	-1.39	0.18
	Sensitive Bodily Regions touched by an Acquaintance									
	B	SE	*β*	*t*	*p*	B	SE	*β*	*T*	*p*
Interoceptive Deficit (EDI-3)	0.06	0.18	0.30	0.34	0.74	0.16	0.17	0.58	0.91	0.37
DCQ	0.18	0.18	0.86	1.01	0.32	-0.18	0.17	-1.30	-1.05	0.30

Insensitive Bodily Regions touched by an Acquaintance										
	B	SE	*β*	*t*	*p*	B	SE	*β*	*T*	*p*
Interoceptive Deficit (EDI-3)	0.23	0.18	0.93	1.32	0.20	0.11	0.18	0.39	0.62	0.54
DCQ	0.09	0.18	0.35	0.51	0.61	-0.12	0.18	-0.81	-0.65	0.52

Notes: *EDI-3*, Eating Disorder Inventory-3; *DCQ*, Dysmorphic Concern Questionnaire

5.2.6 Discussion

This study aimed to investigate imagined social touch responses provided from a loved one and an acquaintance, in individuals with high and low levels of BIDs. In order to achieve this, a novel and newly developed mobile application ‘The Virtual Touch toolkit’ was employed to understand whether individual differences in levels of body image and dysmorphic concerns, factors key in the maintenance of disorders such as AN, impacted participants pleasantness of touch to specific body regions. This is the first investigation to examine soothing and unpleasantness of touch from a loved one compared to an acquaintance using a virtual mobile phone application, focusing on high and low levels of BIDs.

As anticipated, results demonstrated that touch from a familiar person i.e., a loved one was evaluated as being more soothing compared to touch from an unfamiliar person i.e., an acquaintance which was seen as more unpleasant. This finding supports previous research in that the relationship shared between the touch giver and receiver influences pleasantness of touch (Suvilehto et al., 2015, 2019, 2021). If the touch giver is closer and more familiar to the touch receiver, the more pleasant this touch is and the more areas are evaluated as pleasant (Jones & Yarbrough, 1985; Nummenmaa et al., 2016; Strauss et al., 2020; Suvilehto et al., 2015, 2019) and if the touch is from a stranger, then this touch is largely unpleasant and the body regions that can be touched are more restricted (Suvilehto et al., 2015). When looking at individual body parts it was revealed that regardless of levels of BIDs, touch from a loved one was more soothing for all body regions including the buttocks and genitals. Touch for an acquaintance was restricted to the arm and hands for high levels of BIDs and for the hands only for low levels of BIDs. This finding largely supports that of Suvilehto et al. (2015), who found that partners and loved ones were able to touch more body regions, with intimate partners being able to also touch regions such as the genitals and buttocks. Strangers were only accepted to touch the hands and upper torso only.

It was expected that individuals with high levels of BIDs would find touch unpleasant regardless of the touch giver. This expectation is based on findings from prior investigations focusing on AN which revealed that the more severe the body image disturbances, the more uncomfortable and less plausible individuals with AN will be involved in physical intimacy (Cash et al., 2004). Furthermore, Crucianelli et al. (2016), who found that AN patients rated touch as less pleasant than healthy controls. Based on this, it was anticipated that the high levels of BIDs group would evaluate touch as unpleasant regardless of the touch giver. Surprisingly, this was not the case in the current study, as we did not observe any differences between high and low levels of BIDs in their evaluation of touch, which offers support for both Crucianelli et al. (2021) and Tagini et al. (2023), who did not observe any group differences in the pleasantness ratings of social touch. The findings from the current study partially refutes what was found in study 2, in that women with AN rated self-directed touch as more unpleasant than healthy controls. Nevertheless, it was anticipated that due to pleasantness and soothing of touch measuring a comparable positive modalities of touch, high levels of BIDs would not find touch soothing and rate touch from a loved one unpleasant as individuals with AN do. Instead, it was demonstrated that individuals with high levels of BIDs evaluated imagined social touch to social body regions from a loved one as most soothing and that unpleasantness to touch was observed when the imagined social touch was from an acquaintance to intimate body regions.

Nonetheless, the lack of differences between high and low levels of BIDs groups in this study instead offers further support for the findings from Bischoff-Grethe et al. (2018). These researchers found that both individuals with recovered AN and healthy controls displayed comparable responses to both the anticipation and receipt of touch. Both groups rated affective touch as pleasant, and both had intact brain responses to touch. Although this study did not involve the recruitment of people with recovered AN, the findings from this study suggests that even individuals with body image disturbances display typical responses to touch. One possible clarification for this could be explained by a learned experience of receiving touch (Korkmaz et al., 2011). For example, individuals in the high levels of BIDs group may have comparable levels of previous, current, and intimate touch to the low levels of BIDs group and have learned that this touch is pleasant. Based on this assumption, the high levels of BIDs group may have used this constant experience of touch to guide their evaluation (Korkmaz et al., 2011). Another possible explanation could be that the high levels of BIDs individuals may struggle with more complex social situations, involving a dynamic of various interactions of more complex social processing such as theory of mind (Kucharska-Pietura et al., 2004; Russell et al., 2009), as opposed to less complex social situations such as receiving pleasant touch from another individual (Sedgewick et al., 2001). Furthermore, touch deprivation during the Covid-19 pandemic (Von Mohr et al., 2021) could also explain findings for this study. Data collection for this study began during the Covid-19 pandemic and as such the unpleasantness towards touch from an acquaintance may be consequent to fear of touching another and social distancing to avoid infection, a fear instilled towards individuals unknown to us (Burleson et al., 2022). It could have been that this fear and unpleasantness towards touch may have manifested post pandemic, altering how individuals respond to touch from someone less familiar (Burleson et al., 2022). Most importantly, a possible key explanation for the above findings could be consequent to the population being high EDs risk and not having a formal clinical diagnosis of an eating disorder such as AN, who do display atypical responses to touch (Bellard et al. 2022; Crucianelli et al., 2016; 2021; Davidovic et al., 2018). As a result of this, it is difficult to draw conclusions and offer an explanation as to why the high levels of BIDs group evaluated touch responses comparable to the low levels of BIDs group.

As estimated, high levels of BIDs individuals evaluated intimate regions as unpleasant and social regions as soothing, which was also the case for low levels of BIDs individuals. Intimate regions in this study included the abdomen and thighs, which are key body regions more susceptible to concern from both eating disorder populations (Keizer et al., 2011, 2016; Spitoni et al., 2015) and the general population (Ralph-Nearman et al. 2019, Bellard et al. 2021; Irvine et al. 2019). Based on the findings of previous research, the abdomen, a region classified as a weight sensitive region, has been identified as an area women find unattractive and are less satisfied with (Bauer et al., 2017; Bellard et al., 2020; Ralph-Nearman et al., 2019; Horndasch et al., 2012). This body region is also more susceptible to size overestimations in eating disorder patients (Keizer et al., 2011; Spitoni et al., 2015), which could be a result of enhanced intensity of touch and/or interoceptive sensitivity to touch to this region. Thus, this could explain why the low levels of BIDs group demonstrated unpleasantness to touch to this region, as the general population also demonstrate concern to this weight sensitive region (Bauer et al., 2017; Bellard et al., 2020; Ralph-Nearman et al., 2019; Horndasch et al., 2012).

However, frequency of touch cannot offer full explanation for the difference in soothing/unpleasantness of touch for loved ones compared to an acquaintance. It is not always the case that individuals experience more frequent touch from a loved one i.e., a romantic partner and less from an acquaintance (Emmers & Dindia, 1995). Individuals may have a neighbour who they experience a large amount of touch from i.e., hand shaking, or some individuals in the current study may not have intimate romantic relationships (Emmers & Dindia, 1995) or be in a relationship. Some individuals may experience a lot of touch from a loved one or an acquaintance which may not necessarily have a positive intention (for a review see Saarinen et al., 2021). Therefore, another alternative explanation for the above findings could be explained by levels of emotional awareness. Interestingly, the results from the current study revealed that greater levels of emotional awareness, i.e., one’s ability to understand the connection between internal bodily sensations and emotional states (Mehling et al., 2012), measured through the Interoceptive Deficit scale of the EDI-3, was associated with higher soothing ratings for imagined touch from a loved on to both intimate and social regions for the whole sample combined and also for the high levels of BIDs group. This supports previous findings demonstrating that affective touch is important for emotional regulation in adults (Casico, Moore, & McGlone, 2019). The hedonic value of observing touch, is driven by the emotional sensations which have been conveyed by previous touch experiences

(Hertenstein et al., 2006). Therefore, it is expected that touch pleasantness is mediated by emotional awareness, as without this understanding of emotional awareness of the self, participants are not able to connect touch and feelings together. This finding adds to the current literature on social touch as we provide evidence of the key involvement of emotional awareness in tactile interactions in individuals with high levels of BIDs.

Overall, results from the current study offer important findings and may provide vital future implications for touch investigations focusing on clinical populations such as AN. Specifically, touch from a researcher, who in most instances is unfamiliar to the participants, may negatively influence the experience and evaluation of touch. Therefore, it would be interesting to measure atypical responses to affective touch in individuals with AN, but assessing this in relation to stranger touch (from a researcher) compared to a loved one (their partner), to assess whether atypical responses are specific to the relationship to the touch provider or whether these atypical response occur regardless of who they are touched by i.e., occur when touch is given from their partner (for a review, see Saarinen et al., 2021; Thompson & Hampton, 2011). If there is an impaired affective touch system, then it is expected that these atypical responses will manifest regardless of the relationship between the touch giver and receiver. Furthermore, including touch from a loved one, such as a partner, would make the touch feel more comparable to a real-life setting.

In addition, given that pleasantness of touch is largely driven by the relationship/bond between the touch giver and receiver, with closer bonds deemed to be more pleasant compared to stranger touch (Suvilehto et al., 2015, 2019), in future, it would be interesting to further explore different social relationships to the touch receiver in individuals with AN using this application. Particularly, to investigate whether soothing/unpleasantness responses to touch differs depending on bond, like in Suvilehto et al. (2015, 2019, 2021), and also considering individuals crucial in the assistance of the recovery of this population, such as touch from therapists or clinicians. For example, previous research has found that patients report positive responses to touch when given from nurses (Weiss, 1990). Hence, this could be achieved through the Virtual Touch

Toolkit, which allows you to assess soothing and unpleasantness of touch from an array of relationships, including touch in a clinical setting.

Nevertheless, findings from this study could have arisen due to limitations identified. Firstly, individuals who participated were subthreshold and only at risk of body image disturbances and did not have a formal diagnosis of a body image disorder such as AN, which would have accounted for the lack of differences between high and low levels of BIDs groups. Given that these individuals are not clinical populations, they may not struggle with maintaining relationships and do not display atypical responses to touch comparable to individuals with AN do. Future studies should concentrate on examining soothing and unpleasantness of touch by using structured interviews (i.e., Eating Disorder Examination Interview (Fairburn et al., 1993, 2008), rather than relying on EDI-3 EDCR scores (Garner, 2004) to assign participants into groups. The population in this study may not be a true representative of each group and may have accounted for the lack of observed differences between high and low levels of BIDs groups. Hence, in the future, it would be interesting to focus on individuals with AN with a formal diagnosis, to further investigate soothing and unpleasant responses to touch using this application. Also, further research focusing on touch with high EDs risk populations should consider levels of exposure to positive touch and being in a relationship in which touch is given on a daily basis, which are both important factors which could influence responses to touch (Grewen et al., 2003; Triscoli et al., 2017). Previous research has revealed that individuals in satisfying relationships experience and rate touch as more pleasant, than those in less satisfying relationships (Ditzen et al., 2007; Grewen et al., 2003; Triscoli et al., 2017). Based on this assumption, it could be that some high levels of BIDs individuals who are in a relationship or married experience greater exposure to touch and more probable to tolerate and rate this touch as more soothing, than those who are single (Triscoli et al., 2017). Thus, this sample may be more representative of the population in a relationship and experience greater levels of touch, which could account for the comparable responses to touch to the low levels of BIDs group.

In addition, touch deprivation during the Covid-19 pandemic could have contributed towards the findings for the current investigation (Meijer et al., 2022; Von

Mohr et al., 2021). This could be the case given that data collection began during the pandemic, which was a time when social distancing measures were in place and touch towards an acquaintance may be seen as unpleasant given the fear of touching another and the risk of infection. This was a fear instilled into the population particularly for people unknown to you and outside your "social bubble" (Burleson et al., 2022). This fear of touching a less familiar individual may have manifested post-pandemic and could have accounted for the unpleasant responses to imagined social touch from an acquaintance (Burleson et al., 2022).

5.2.6.1 Conclusions

In conclusion, findings from this study demonstrate that soothing responses to imagined social touch is largely influenced by social context and the relationship and bond shared between the touch giver and the touch receiver. Touch is evaluated as more soothing when provided from a familiar person such as a loved one, compared to an unfamiliar person such as an acquaintance (Jones & Yarbrough, 1985; Nummenmaa et al., 2016; Strauss et al., 2020; Suvilehto et al., 2015, 2019). Furthermore, we add to the current literature by providing a first account of the key involvement of emotional awareness in imagined social touch in individuals with high levels of BIDs.

Furthermore, given the potential positive use of the Virtual Touch Toolkit with individuals with high levels of BIDs, future research could pilot this application as an intervention for atypical responses to touch in clinical populations such as AN. This could be achieved by incorporating longitudinal methods physiological and behavioural responses to touch. Using self-touch through this application could have positive, soothing effects on reducing stress responses such as cortisol levels (Dreisoerner et al., 2021; Neff & Germer, 2013). Thus, this pilot could be developed to assess whether administering self-touch using this application positively impacts and enhances physiological and behavioural responses to touch in clinical populations. In addition, given this application's success in responses to imagined social touch with high levels of BIDs in the current study, this tool can also be used to assist with interpersonal difficulties associated with AN and the atypical responses to receiving social touch from different relationships. The Virtual Touch Toolkit can be used as a measure for physiological and behavioural responses to imagined tactile interactions to different social relationships in AN patients such as family and friends as well as health professionals. This would be useful given that previous research has found that touch positively facilitates the interaction between health professionals and their patients through setting boundaries and emotional closeness (Kelly et al., 2018). This positive interaction is important in body-orientated psychotherapies for AN, given that physical contact between a therapist and the patient is key in the treatment (Vandereycken et al., 1987). The Virtual Touch Toolkit is a ‘virtual’ space which is a depiction of real-life scenarios in which patients can interact safely without the stress of physical contact. Patients can engage in self-touch exercises to focus on their own body but can also get themselves familiar with various interpersonal touch whether from a loved one, clinician or even a stranger. Overall, given the beneficial uses of this tool in rehabilitative purposes in imagined social touch, future research should test this with individuals with AN.

Chapter 6

Neural underpinnings of affective touch and the association with eating behaviours: A Transcranial Magnetic Stimulation (TMS) study

As revealed in study 2 (discussed in Chapter 4), both individuals with AN and RAN rated vicarious affective touch as less pleasant when given to self and did not differ to healthy controls when providing ratings to touch when given another person. Based on this, we wanted to understand the neural underpinnings of self-directed and other-directed touch which could be mediating the atypical responses to self-directed touch in AN.

In order to examine this, we aimed at investigating whether different neural substrates underpin self vs. other-directed touch in relation to ED symptomatology. Affective touch involves several key brain regions in addition to the Insula Cortex, some of which are involved in social cognition, such as the mPFC and have also demonstrated links with S1. For instance, the mPFC is a region largely involved in theory of mind and coding of social reward of tactile stimuli (Gordon et al., 2013). Furthermore, studies have revealed correlations between ratings of touch pleasantness and S1 activation (McCabe et al., 2008; Gazzola et al., 2012).

The current study (Study 4) investigated whether inhibition of the right vmPFC and S1 is linked with atypical affective touch responses and if this is associated with reduced interoceptive awareness and ED symptomatology. Specifically, we wanted to investigate whether disruption of the vmPFC causes a reduced pleasantness ratings for CT-optimal touch compared to non-optimal touch for other-directed compared to self-directed touch. In addition, whether this effect correlates with ED symptomatology such as interoceptive deficits, body image concerns and negative body-image perception. Also, we aimed at assessing whether disruption to S1 resulted in reduced pleasantness ratings overall and not CT-optimal specific. Furthermore, whether this effect was associated with reduced interoceptive awareness, more severe inaccuracies in the visual mental image of the body, and overestimation of tactile distances.

This was achieved through participants receiving offline inhibitory continuous theta-burst stimulation (cTBS) over the right vmPFC, S1 and Vertex before providing third-party ratings of touch pleasantness delivered across 5 body sites (Cheek, back, ventral forearm, upper arm, and palm) and 3 velocities (0 cm/s, 5 cm/s, 30 cm/s) for two tasks (self-directed vs. other-directed touch) (Trotter et al., 2018) (See Chapter 2.1.1). Nevertheless, no study to date has investigated this using TMS to determine the role of specific regions particularly the mPFC and S1 in affective touch impairments in AN.

6.1 Introduction

Interpersonal touch plays a key role in non-verbal communication with another and is crucial in the formation and maintenance of relationships (Brauer, Xiao, Poulain, Friederici, & Schirmer, 2016; Cascio, Moore, & McGlone, 2019; Morrison, Löken, & Olausson, 2010; von Mohr, Kirsch, & Fotopoulou, 2017). The more one experiences touch from another, the stronger the bond formed and the more likely this relationship is to be maintained (Gallace & Spence, 2010). Tactile experiences during early childhood are crucial for the development of the social brain (Cascio et al., 2019). If this is not experienced, this can have long lasting impact on the brain such as reduced activation and volume of grey matter (Nelson et al., 2014).

Touch is comprised of the discriminative touch involving somatosensory networks and the affective modality (McGlone et al., 2014). The affective component of touch is the processing of the hedonic value of touch and involves the activation of unmyelinated C-Tactile afferents (CTs), which are located only in the hairy components of the skin (Liu et al., 2007; Olausson et al., 2010). Touch to this portion of the skin is typically perceived as pleasant in typically developing populations (Ackerley et al., 2014; Croy et al., 2016; Löken et al., 2009). CTs respond when gentle stroking of the skin is applied in velocities between 1 cm/s and 10 cm/s, with the greatest response occurring when touch is given at skin temperature at a velocity of 3 cm/s (Ackerley et al., 2014; Löken et al., 2009; McGlone et al., 2014).

Previous fMRI investigations have offered insight into the main cortical regions involved in affective touch processing (Gordon et al., 2013). These investigations have supported the involvement of the anterior and posterior Insula Cortex in actual and anticipated experience of touch (Björnsdotter et al., 2009; Craig, 2002; Gordon et al., 2013; Morrison, 2016).

As well as the Insula Cortex, prior neuroimaging investigations have discovered that other key neural networks are involved and are important in the processing of affective touch. These are areas involved in social perception and social cognition (Gallagher & Firth, 2003; Koster-Hale & Saxe, 2013). One of these brain regions includes the medial Prefrontal Cortex (mPFC) (Chen et al., 2020; Gordon et al., 2011, 2013; Voos et al., 2013), and specifically the ventromedial Prefrontal Cortex (vmPFC) (Davidovic et al., 2019). The medial prefrontal cortex (mPFC) is important for human social cognition and behaviour. The mPFC is well known for its involvement in visual perspective taking, a low-level mechanism, part of the theory of mind system and is also largely involved in mentalising abilities and is implicated in inferring other people's intentions and mental states as well as attributing emotional states to others (D'Argembeau et al., 2007; Sperduti et al., 2011). The mPFC has previously found to be more activated in response to when participants received manual brush stroking to the arm, compared to when they received brush stroking to the palm (Gordon et al., 2013). As suggested by Gordon et al. (2013), coactivation of the amygdala, Insula and mPFC during CT-optimal touch represents the encoding of the social relevance and reward of that touch.

Furthermore, as well as the mPFC, the primary Somatosensory Cortex (S1), a region involved in touch discrimination aspects such as detection of tactile touch to the skin (Cohen et al., 1991) and two-point discrimination of touch to the skin (Tegenthoff et al., 2005) has suggested to be involved in the encoding of social touch (Bolognini et al., 2013). This region is involved in distinguishing pleasant, neutral, and unpleasant/painful touch (Gordon et al., 2011; Morrison et al., 2011; Rolls et al., 2003). Previous literature which suggests a possible connection with this region and touch pleasantness to various body regions (Gazzola et al., 2012; McCabe et al., 2008) nevertheless, have not fully offered support for a strong connection between this region and social touch, specifically CT-optimal touch, as factors such as motivation and attention are confounds which play a role (Case et al., 2016; McGlone et al., 2014; Olausson et al., 2002, 2008). However, it is unclear as to whether activation of S1 during the activation and observation of touch is linked to the hedonic value of the touch received (Gazzola et al., 2012), the exact involvement of this region remains under dispute (Case et al., 2016). For example, a more recent fMRI and repetitive Transcranial Magnetic Stimulation (rTMS) study by Case et al. (2016) revealed that after participants received brush stroking to the hand proceeding from rTMS over S1, touch discrimination was reduced and rated as more intense, but pleasantness ratings remained unaffected. A case study conducted on a patient with acute polyradiculitis and polyneuropathy i.e., loss of large-diameter myelinated afferents with a functioning CT-afferent system, demonstrated deficits in discrimination of touch still demonstrated typical pleasantness responses to receiving CT touch. fMRI findings from this investigation revealed activation of the Insula Cortex but not S1 (Olausson et al., 2002). Therefore, results from this study suggest that S1 is solely involved in touch discrimination and not in the hedonic value of affective touch and therefore that pleasantness of touch is processed in other regions excluding S1. Despite research providing evidence that pleasantness of touch is processed outside of S1, several investigations have revealed fMRI correlations between ratings of touch pleasantness and S1 activation (McCabe et al., 2008; Gazzola et al., 2012). Yet, although the case, these studies did not use CT-optimal touch in their investigations and so make it difficult to draw conclusions that S1 plays a key role in affective touch. A study conducted by Morrison et al. (2011) revealed higher S1 activation when perceiving someone receiving touch delivered at CT-optimal velocity (3 cm/s) as opposed to non-optimal velocities (30 cm/s). However, although activated during the perception of CT-optimal touch, S1 was also activated during CT non-optimal touch, therefore, this study could suggest that S1 is more involved in perception of touch regardless of velocity of touch and that this region is not required specifically during the process of affective touch.

More recently, it has been revealed that the affective component of touch is altered in Anorexia Nervosa (AN), with these patients perceiving and evaluating gentle touch as less pleasant compared to healthy controls, not only during the direct experience of touch (Crucianelli et al., 2016, 2019, 2021; Davidovic et al., 2018), but also during the anticipation of affective touch (Bischoff-Grethe et al. 2018; Crucianelli et al., 2021). AN is an eating pathology which involves an abnormal preoccupation with the control of eating behaviours due to a fear of gaining weight. Individuals with AN display body image disturbances which occur due to cognitive, affective, and perceptual abnormalities (Gaudio & Quattrocchi, 2012). It is believed that body image disturbances, involving overestimation of body size and body dissatisfaction is key in the development, maintenance, and relapse rates (APA, 2013). For example, previous research has highlighted that people with AN display abnormal processing of tactile stimulation and have impairments in the perception of affective touch, as they tend to overestimate the distance on the skin between two tactile points (Spitoni et al., 2015; Keizer et al., 2011, 2012), which has also found to be associated with overestimation in body image perception (Gaudio et al., 2014; Keizer et al., 2011, 2012). Furthermore, as well as perceptual discrepancies, individuals with AN also display deficits in interoceptive awareness and as a result, struggle to interpret internal sensations of their body such as hunger or pain (Kaye et al., 2009; Kerr et al., 2016; Monteleone & Maj, 2013; Oberndorfer et al., 2013; Perez et al., 2013; Strigo et al., 2013) which is key also in the maintenance and development of body image distortions (Kaye et al., 2009; Nandrino et al., 2012; Strigo et al., 2013). Prior investigations have suggested an association with interoceptive awareness deficits to a dysfunction of the Insula Cortex in AN (Kerr et al., 2016). It has been proposed that as people with AN have disruption in the functioning of the Insula Cortex, they lack the ability to integrate sensory experiences with their affective value (Nunn et al., 2008) and display a mismatch between internal and external sensations (Bischoff-Grethe et al., 2018).

In addition to the Insula Cortex (Bischoff-Grethe et al., 2018; Davidovic et al., 2018; Wierenga et al., 2020), other regions have been found to impaired in affective touch processing in individuals with AN, some of which are involved in social perception and social cognition. One of which is the frontal pole (Davidovic et al., 2018), this region in humans includes a medial and lateral part, often referred to as the vmPFC (Koechlin, 2011), right temporal pole, left caudate nucleus, bilateral precuneus (Davidovic et al., 2018) and left putamen (Wiergenga et al., 2020). Yet, research concerning the underpinnings of affective touch in eating disorders is limited, as there are only 3 neuroimaging investigations to date, which have mainly focused on the Insula Cortex. Other studies which have assessed impairment in affective touch processing have focused on behavioural measures (Crucianelli et al., 2016, 2021) which too are also limited.

Therefore, more investigations are required to understand which brain regions are impaired in this processing of affective touch in eating disorders, to better understand if impairment is in the hedonic aspect of touch, perception of touch or anticipation of touch. Also, whether the impairment is more top-down as opposed to bottom-up.

6.1.1 The Current Study

Based on previous research, this current investigation aims to establish whether inhibitory Transcranial Magnetic Stimulation (rTMS) over the right S1 and vmPFC is causative of atypical vicarious affective touch responses, in relation to ED symptomatology. TMS is a non-invasive brain stimulation technique which allows to investigate a causative relationship between a brain region and a specific behaviour in healthy individuals, by creating temporary interference of neural activity. In creating this temporary interference with neural activity, investigators can understand whether the targeted brain region is involved with a specific function (Hallet, 2007). We therefore applied this approach to temporally inhibit the brain regions supposedly involved in the processing of self-directed vs. other-directed vicarious affective touch prior to participants observing touch delivered over 5 body regions (Ventral forearm, upper arm, back, cheek and palm), at optimal and non-optimal velocities (0 cm/s, 5 cm/s and 30 cm/s). We also administered several questionnaires assessing various facets of ED symptomatology such as eating attitudes through the EDI-3 (Garner, 2002), interoceptive awareness through the MAIA questionnaire (Mehling et al., 2012), tactile estimation through the TET (Keizer et al., 2011) and touch experiences and attitudes towards touch through the TEAQ (Trotter et al., 2018). This way we aimed at establishing whether temporary disruption of these brain regions which may impact the perceived pleasantness of vicarious touch is also associated with ED symptomatology. Due to the vmPFC being largely involved in affective Theory of Mind (ToM) (rewarding value of social/affective touch) and the perception of affective touch, it is anticipated that disruption of this region should result in reduced pleasantness ratings for CT-optimal touch compared to non-optimal touch, which should correlate with ED symptomatology. Furthermore, if the hedonic value of touch is intrinsically related to the physical characteristics of tactile stimuli such as force, velocity, then disruption to S1 should result in reduced pleasantness ratings which should not be CT-optimal specific.

Furthermore, this investigation aimed to examine the links with pleasantness ratings of affective touch and eating disorder traits such as interoceptive deficits and body image concerns (Crucianelli et al., 2016; Davidovic et al., 2018; Kaye, Fudge, & Paulus, 2009; Pollatos et al., 2008) and body image misperception (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016; Perez, Coley, Crandall, Di Lorenzo, & Bravender, 2013). If as suggested by Matsumoto et al. (2006), that the vmPFC is also linked to interoceptive deficits in AN, it was expected that there would be correlations with reduced interoceptive awareness and with body image concerns and body-image perception, which has been previously shown in both Xu et al. (2017) and Miyake et al. (2010) investigations. If S1 is necessary for the processing of affective touch, then disruption to this brain regions should be causative of reduced affective interoceptive stimuli, as high levels of body dissatisfaction are related to more severe inaccuracies in the visual mental image of the body, and overestimation of tactile distances. These are believed to occur due to disturbances in somatosensory aspects of body image (Keizer et al., 2011) which is the resulting of abnormal connectivity of the visual and somatosensory brain regions in individuals with AN (Favaro et al., 2012).

6.2 Methods

6.2.1 Participants

A total of 18 right-handed females aged 18-35 (Mage = 23, SD= 4.26), were recruited and subject to all experimental conditions. All participants were either students from Liverpool John Moores University or from the general public. The rationalisation for only including females in this investigation is that they are more susceptible to eating disorders compared to males (Striegel-Moore, 2009).

All participants had normal or corrected to normal vision (with glasses/contact lenses), no skin conditions such as eczema, no chronic pain conditions such as arthritis and had no past history of epilepsy or any form of neurological disease, no psychiatric conditions including a current or previous diagnosis of an eating disorder, did not have a cardiac pacemaker or any form of metal implants in the head and were not pregnant. All inclusion criteria were checked prior to testing to ensure participants met all inclusion and those meeting the exclusion criteria did not participate. To ensure this and prior to testing, participants were administered with a TMS safety screening questionnaire to check for their eligibility to receive brain stimulation. All participants were naïve to the true aims of the investigation. The study's aims were made clear when participants were debriefed through the debrief sheet presented at the end of the study.

This investigation was conducted in accordance with the Helsinki declaration of ethical standards. The study protocol was approved by the LJMU's University Research Ethics Committee (UREC) (protocol: 21/PSY/002). All participants gave full informed consent to take part in the study. Participants were provided with a £15 amazon voucher and level 4 BSc Psychology students were awarded course credits, as compensation for their time.

6.2.2 Measures

6.2.2.1 Observed Affective Touch Task

The observed affective touch task consisted of 6 second Touch videos of males applying touch to female actors at different body regions. Touch was delivered across five different body regions (non-affective body region such as the palm vs. Affective body regions such as the ventral forearm, upper arm, cheek and back) with three different velocities (static (0 cm/s), slow (5 cm/s) and fast (30 cm/s)).

The order in which the videos were viewed, was fully randomised amongst participants. After viewing each video, participants were probed to respond to one of two questions: "How pleasant do you think that action was for the person being touched?" (other-directed touch) using a VAS ranging from 0= "very unpleasant" to 100= "extremely pleasant", and "How much would you like to be touched like that?" (self-directed touch) using a VAS ranging from 0= "not at all" to 100= "extremely" (Walker, Trotter, Woods, & McGlone, 2017; Bellard et al. 2022).

Both tasks were blocked, so participants only answered one question per block and blocks were counterbalanced. For each block there was a total of 45 videos displayed (15 per body region, 3 per velocity). Overall, across all conditions and blocks, there was a total of 270 videos presented, each displayed in 240 p YouTube quality (Trotter et al., 2018) (See figure 6.2.2.1.1 for a visualisation).

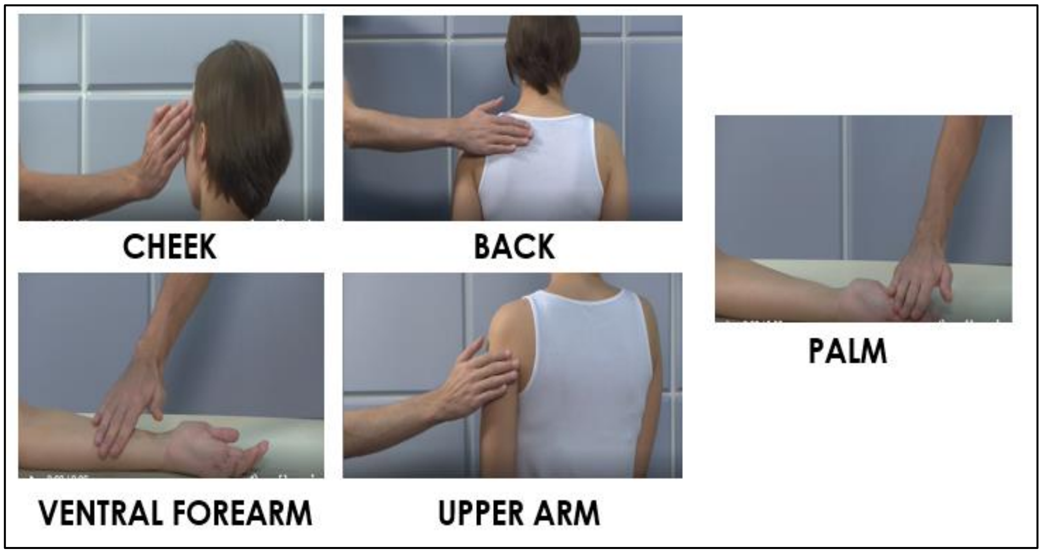

Figure 6.2.2.1.1 *Visual illustration of the 5 body sites (CT-innervated body regions: Ventral Forearm, Upper Arm, Cheek and Back vs. the non-CT innervated palm) from the affective touch videos used in this study.*

6.2.2.2 Tactile Estimation Task

The Tactile Estimation Task (TET) has been previously used with AN populations (Keizer et al., 2011). The TET for this investigation involved applying two tactile stimuli simultaneously to the right forearm of the participants prior to any brain stimulation. Participants were asked to wear clothing that allowed easy access to their forearm.

As outlined in Chapter 2.4.1, during this task, participants were provided with a blindfold and asked to estimate the distance between the two tactile stimuli using their thumb and index finger and place their fingers onto the whiteboard provided. The distance between the thumb and index finger was then measured by the researcher using a ruler and each trail distance was noted. The distance the tactile points on the calliper was placed on the participants forearm differed i.e., 50 mm, 60 mm and 70 mm measurements were used. These measurements were applied randomly to the same body region to prevent participants using previous estimates to guide their current estimation of the same measurement, which in turn could result in order effects making them more accurate (Keizer et al., 2011).

To ensure participants did not experience any discomfort during this task, only female researchers were present during this proportion of testing (and during all testing) (See Chapter 2, section 2.4.1).

6.2.3 Self-report Questionnaires

6.2.3.1 Screening Questionnaire (Appendix 1)

A set of 8 screening questions was sent out to participants prior to testing to determine participants' eligibility to take part. This questionnaire asked participants to state "True" or "False" to a series of statements. These statements included "I am Female" and "I confirm that I have not got a current or previous diagnosis of an eating disorder". A final question asked participants if they have read the information sheet provided and if they agree to take part in the study by clicking on the "I agree" option if they do. If a participant answered "false" to any of these statements, the researcher contacted them via email address provide to let participants know that they were unable to take part. In this email, participants were provided with the debrief sheet so they can understand what the study was about.

6.2.3.2 TMS Safety-screening Questionnaire (Appendix 9)

Before the experimental session, a 20-item pre-screen questionnaire was administered ensuring participants suitability to receive brain stimulation (Keel, Smith, & Wassermann, 2001). In this questionnaire, participants responded to the questions by answering yes or no and in some situations, were asked to provide additional information on questions such as any medication or when and how many brain stimulation sessions they have had in the past.

The questions in this questionnaire focused on if participants had any neurological disorders, family history of Neurological disorders, if participants have epilepsy or have first degree relatives who have epilepsy, if participants have any non-removable metal such as metal in the brain and that the participant is pregnant during time of testing etc. This was to ensure participants met the inclusion criteria for the study (see questionnaire in appendix 9). This questionnaire was checked prior to testing and at the beginning of each testing session to ensure no changes since the last session. Participants with enhanced risk of the side effects of TMS, based upon answers to these questions, were excluded from the investigation at any time (Rossi, Hallett, Rossini, & Pascual-Leone, 2011).

6.2.3.3 Demographics Questionnaire (Appendix 2)

Demographic information that was taken from participants included their age, gender, ethnicity, and date of birth. Questions also asked participants to declare whether they have any skin conditions such as psoriasis, eczema etc. Body mass index (BMI) was physically obtained by the researcher. Height was collected by using a stadiometer and a calibrated bioimpedance digital scale (OMRON BF511) was used to measure participants' body weight.

6.2.3.4 Multidimensional Assessment of Interoceptive Awareness (Appendix 3)

The Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling et al., 2012) is a 32-item questionnaire which assesses eight components of interoceptive awareness (see Chapter 2, section 2.3.3). In this study, this was used to understand whether a reduced interoceptive awareness was associated with changes in pleasantness ratings consequent to disruption to vmPFC or S1.

6.2.3.5 Eating Disorder Inventory-3 (EDI-3) (Appendix 5)

The Eating Disorder Inventory-3 (EDI-3) (Garner, 2004) is a 91 item self-report questionnaire assessing eating disorder symptomatology. This questionnaire assesses 12 subscales, 3 of which assess eating disorder symptomatology (see Chapter 2, section 2.3.5). In this study, this measure was used to understand whether facets associated with ED symptomatology were associated with changes in touch pleasantness ratings consequent to disruption to vmPFC or S1.

6.2.3.6 Dysmorphic Concern Questionnaire (Appendix 6)

The Dysmorphic Concern Questionnaire (DCQ) (Oosthuizen et al.,1998) is a short questionnaire used to measure an individual's concern towards their physical appearance (see Chapter 2, section 2.3.6). This measure was used to determine whether greater concern towards physical appearance was associated with changes in pleasantness ratings after disruption to vmPFC or S1.

6.2.3.7 Touch Experiences and Attitudes Questionnaire (Appendix 7)

The Touch Experiences and Attitudes Questionnaire (TEAQ, Trotter et al., 2018b) is a questionnaire which measures experience and attitudes towards touch (see Chapter 2, section 2.3.7). This questionnaire assessed whether changes in pleasantness of touch consequent inhibition of vmPFC or S1 was associated with experience and attitudes of touch.

6.2.4 Method

6.2.4.1 TMS Procedure

This experiment entailed three separate lab sessions, in which participants were required to undertake all brain stimulation conditions. All of these conditions were counterbalanced amongst participants. All participants underwent three sessions of offline rTMS with a theta-burst protocol, which were delivered over S1, vmPFC and Vertex (as the control region). These TMS sessions lasted 40 seconds (200 bursts, each comprising three pulses at 50% power, 30 Hz frequency, 6Hz burst frequency repeated every 200 ms

(5 Hz), 600 pulses in total) as outlined in Goldsworthy et al. (2012). Brain stimulation occurred prior to the presentation of the observed affective touch task. As the effects of stimulation usually lasts over 1 hour, participants were required to attend three lab sessions. This prevented and ensured no confound of previous stimulation from another brain region could interfere with results.

Prior to the brain stimulation phase, to ensure the right S1, vmPFC and Vertex were correctly localised, we generated individual 3D brain reconstructions of each participant using the Softaxic Neuronavigation system (EMS, Bologna, Italy). In order to achieve this, participant's nasion, Inion, A1, and A2 and 19 points were localised over the participants scalp allowing for the system to create this 3D construction. This software enables for the manual input of the Talairach coordinates to pinpoint the brain areas of interest on the 3D brain reconstruction. Therefore, as a result of the input of the Talairach coordinates, this allows for the accurate navigation of the coil to the brain region of interest. The SofTaxic Neuronavigation system automatically estimates coordinates for each brain region in standard space using an MRI-constructed stereotaxic template. This allows for the localisation of the coil for stimulation. This also ensured that the magnetic pulses were only provided to the right S1, vmPFC and Vertex. Once the coil was tangentially positioned i.e., the handle pointing downwards and was secured over the scalp, stimulation was given to the three brain regions.

During the brain stimulation phase, participants received this protocol to the right S1, vmPFC and Vertex using a 70-mm figure-of-eight stimulation coil (Magstim Double 70 mm Air Film Coil, D70 Air Film Coil), connected to a Magstim SuperRapid^2 Stimulator (The Magstim Company, Carmarthenshire, Wales), this generated a magnetic field up to 0.8 T at the surface of the coil.

Following the methodology of Pollatos et al. (2016) and Willacker et al. (2020), repetitive TMS with a theta-burst protocol was delivered over the right S1 at MNI coordinates (X= 46, Y= -28, Z= 72) (Case et al., 2016) and over the right vmPFC at Talairach coordinates (X= 3, Y= 58, Z= -8) (Davidovic et al., 2019). We focused on targeting the vmPFC, as in addition to the Insula Cortex (Bischoff-Grethe et al., 2018; Davidovic et al., 2018; Wierenga et al., 2020), other regions such as the vmPFC have been found to be impaired in affective touch processing in individuals with AN (Davidovic et al., 2018; Koechlin, 2011). Also, we targeted the vmPFC due to constraints in targeting the Insula Cortex (Knyahnytska et al., 2019; Lee et al., 2020). Furthermore, we targeted this region as the focus of this research was on social touch processing and this region is largely involved in mentalising and inferring and understanding the mental states of others (D'Argembeau et al., 2007; Sperduti et al., 2011) and social reward (Grabenhorst & Rolls, 2011).

Furthermore, we focused on inhibiting S1 due to the involvement of this region in overall touch processing (Case et al., 2016). In relation to eating disorders, high levels of body dissatisfaction are related to more severe inaccuracies in the visual mental image of the body, and overestimation of tactile distances (Keizer et al., 2011). These are believed to occur due to disturbances in somatosensory aspects of body image (Keizer et al., 2011) which is resulting of abnormal connectivity of the visual and somatosensory brain regions in individuals with AN (Favaro et al., 2012).

As a control site, the vertex was stimulated with the induced current running from posterior to anterior along the interhemispheric fissure using Talairach coordinates ($X = 0$, $Y = -44$, $Z = 69$) (Cazzato, Mele, & Urgesi, 2014) (See figure 6.2.4.1.1). The stimulation to the right S1, vmPFC and Vertex occurred prior to the presentation of the observed affective touch task.

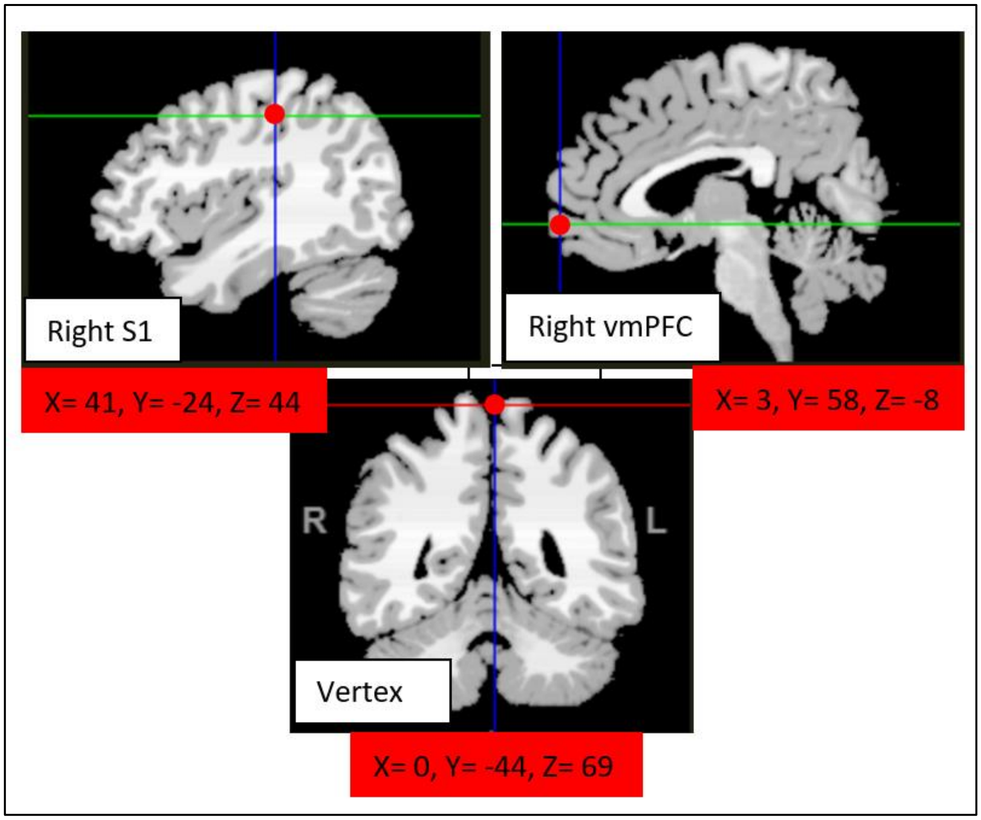

Figure 6.2.4.1.1 *Visual depiction using MRI imaging of the location of each of the three brain regions: right vmPFC, S1 and Vertex. The red dots indicate the position the coil was place on participants' scalp. All coordinates are converted to Talairach.*

For the exact localisation of each brain region, averaged across all participants, see Table 6.2.5.1.2 reported below.

6.2.4.2 General Procedure

All interested participants were emailed the screening questionnaire, safety-screening questionnaire, and asked to fill and send back these prior to their testing sessions being booked in. The TMS safety-screening assessed participants eligibility to safely undergo TMS and the screening questionnaire examined inclusion criteria such as being female, over 18 years of age, no chronic pain and/or skin conditions etc. Information collected from these questionnaires were anonymised and confidentiality was maintained.

Those participants who were eligible, based on their responses from both questionnaires were contacted by the researcher to arrange three testing sessions. It was essential that each session had a minimum of 48 hours in between.

For session one, this lasted 1hr, participants were asked again to complete the TMS safety screening questionnaire. This was to ensure no changes have occurred since completing it via email. Proceeding from this, participants were then asked to complete the demographics questionnaire, EDI-3, MAIA, DCQ and TEAQ. Once finished, participants were instructed to sit comfortably and then completed the tactile estimation task. This TET involved applying two tactile stimuli simultaneously to the forearm, whilst participants were blindfolded. After each trial, participants were asked to estimate the distance between the two tactile stimuli placed at various distances. This was done using their thumb and index finger.

Progressing from this task, the Softaxic Neuronavigation system was used to create a 3D reconstruction of the participants brain. This was achieved through localising the nasion, Inion, A1 and A2 in addition to pinpointing 19 individual points on the scalp. This 3D reconstruction was used to localise the first brain region, by entering the MNI or Talairach Co-ordinates for that specific brain region. This 3D brain reconstruction was saved using a unique participant code. This allowed for the reconstruction to be used for future sessions. After this 3D brain reconstruction was developed, participants received offline TMS with a theta-burst protocol. This protocol involved delivering in 600 pulses for a duration of 40 seconds, to one of the 3 brain regions (right vmPFC, right S1 and Vertex), depending on the counterbalancing. Once stimulation was completed, participants instantly were subject to the observed affective touch task. This required participants to view videos of a male actor applying touch to a female across 5 body sites (ventral forearm, upper arm, cheek, back and palm) with three different velocities (0 cm/s), 5 cm/s and 30 cm/s). After viewing each video, participants were asked to respond: “How pleasant do you think that action was for the person being touched?” (other-directed touch) using a VAS ranging from 0= very unpleasant to 100= extremely pleasant and “How much would you like to be touched like that?” (self-directed touch) using a VAS ranging from 0= not at all to 100= extremely (Walker, Trotter, Woods, & McGlone, 2017) in the order depending on the block counterbalancing. For session 2, which approximately lasted 20 minutes, participants were asked to re-complete the TMS safety screening questionnaire. This session did not require a full 3D brain reconstruction. Instead, only specific points were necessary which included the nasion, A1 and A2 in order to localise the second brain region and to accurately deliver the brain stimulation. After this, participants were subject to the same observed affective touch task, which was also completed in session one.

For session three, which lasted an estimated 20 minutes, participants re-completed the TMS safety screening questionnaire. This was to also ensure no changes had occurred since completing it during session two. Comparable to session two, this session required only specific points which included the nasion, A1 and A2, for the 3D brain reconstruction and for the accurate localisation of the third brain region. After finishing this reconstruction, participants received the same offline TMS with a theta-burst protocol as outlined in session one and two. Once completed, participants viewed and completed the observed affective touch task. Lastly, participants were fully debriefed and provided with a detailed account of what the study was about and the study hypothesis. Overall, this study had a duration of 2 hours, spread across 3 sessions.

6.2.4.3 Statistical analysis and data processing

All data were analysed using SPSS 26 (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.). All demographic information and scores for the self-reported questionnaires are reported as Mean (M) and Standard Deviation of the mean (SD). A significance threshold of $p<.05$ was used as the significance threshold for each of the effects.

Initially, a preliminary analysis including the body sites did not reveal any two-way interaction with TMS sites for both tasks. Only a 3-way interaction was observed for the self-directed touch with velocity and brain sites, and as a result, body sites were collapsed across one another.

A 2-way ANOVA with within-subjects factors of velocity (0 cm/s, 5 cm/s and 30 cm/s) and brain region (vmPFC, S1 and Vertex) was conducted separately for each task (Other-directed touch and self-directed touch). Bonferroni post-hoc tests were conducted to follow up any significant interactions. However, null hypothesis significance is not able to examine whether the data favours the null hypothesis or the alternative hypothesis. In regard to this study, it was not certain whether cTBS over specific regions were causative of significant differences in self-directed and other-directed touch pleasantness ratings. Therefore, statistics specifically relating to the ANOVAs were complemented with Bayesian statistics using JASP (JASP Team, 2022, v0.16.3). In doing this analysis, the strength of the evidence relating to the null or alternative hypothesis could be assessed (Dienes, 2011; Wagenmakers et al., 2018; Keysers, Gazzola, & Wagenmakers, 2020). Default priors in JASP were used. Inclusion BFs quantify the evidence for including a specific main effect or interaction. A Bayes Factor (BF) > 3 indicates evidence for the alternative hypothesis, whereas a BF < .03 is indicative of evidence for the null hypothesis (Jeffreys, 1961). A BF between 0.3 and 3 indicates an inconclusive result which is not in favour of either hypothesis.

Exploratory Pearson's correlations were conducted separately for each task considering the index (Brain Areas X-Vertex (delta effect)) for pleasantness ratings with variables from EDI-3, MAIA, TEAQ and DCQ questionnaires to understand if any effects from brain stimulation on pleasantness ratings correlates with scales specific to ED symptomatology.

6.2.5 Results

6.2.5.1 *Univariate Statistics*

Table 6.2.5.1.1 demonstrates the range scores, means and standard deviations for the demographics, self-report questionnaire scores and TET estimations for all participants. Participants in this sample had an average healthy (normal weight) BMI score. Scores for the DCQ also vary from no dysmorphic concern to great dysmorphic concern, with the average being indicative of low dysmorphic concern towards one's body and keeping with Mancuso et al. (2010) (6.83 ± 4.46; t (17) = 2.395, p = .028). Although participants vary from high interoceptive awareness to displaying severe interoceptive awareness deficits, the sample in this study are more representative of the general population (5.94 ± 5.50; t (17) =0.300, p =0.768) (Clausen et al., 2011). Touch experiences and attitudes were typical of a healthy population, even though some participants displayed lack of touch experiences and lower attitudes towards touch. Participants also demonstrated a slight overestimation in tactile estimation overall and for each individual measurement.

Table 6.2.5.1.1 Range scores for demographics, self-report questionnaires scores and TET estimations for all participants (*n= 18*). The column on the far right displays the mean and standard deviation (in brackets).

	Range	Mean (SD)
Age (years)	18.00 - 35.00	22.00 (4.26)
BMI (kg/cm^2)	20.52 - 36.73	24.19 (4.64)
EDI-3		
Drive for thinness	0.00 - 20.00	7.67 (5.59)
Bulimia	1.00 - 30.00	12.06 (9.85)
Body Dissatisfaction	0.00 - 32.00	9.56 (11.67)
Low Self-esteem	0.00 - 16.00	6.61 (5.46)
Personal Alienation	0.00 - 14.00	5.39 (4.39)
Interpersonal Insecurity	0.00 - 13.00	5.33 (4.03)
Interpersonal Alienation	1.00 - 16.00	4.50 (3.65)
Interoceptive Deficit	0.00 - 26.00	5.94 (6.28)
Emotional Dysregulation	0.00 - 14.00	4.33 (3.40)
Perfectionism	0.00 - 21.00	7.67 (5.40)
Ascetism	0.00 - 14.00	4.11 (3.72)

Maturity Fear	0.00 - 20.00	8.11 (5.36)
Composite Score	4.00 - 59.00	29.28 (18.70)
DCQ (max 21)	1.00 - 15.00	6.83 (4.20)
MAIA		
Noticing (max 5)	1.00 - 4.00	2.78 (0.87)
Not Distracting (max 5)	0.00 - 3.67	2.35 (0.93)
Not Worrying (max 5)	0.33 - 4.00	2.18 (1.03)
Attention Regulation (max 5)	0.43 - 3.71	2.24 (0.83)
Emotional Awareness (max 5)	0.80 - 4.00	2.84 (0.90)
Self-regulation (max 5)	0.75 - 4.00	2.33 (0.79)
Body Listening (max 5)	0.00 - 3.33	1.65 (1.02)
Trusting (max 5)	0.67 - 3.67	2.22 (0.70)
TEAQ		
Friends and family touch (max 5)	2.18 - 4.64	3.57 (0.68)
Current intimate touch (max 5)	2.43 - 4.64	3.78 (0.68)
Childhood touch (max 5)	2.67 - 5.00	3.99 (0.76)
Attitude to self-care (max 5)	3.00 - 5.00	3.97 (0.75)
Attitude to intimate touch (max 5)	2.00 - 5.00	4.06 (0.81)
Attitude to unfamiliar touch (max 5)	2.00 - 4.00	2.87 (0.71)
Tactile Estimation Task (TET)		
Baseline	25.00 - 45.00	34.17 (6.47)
50mm	38.60 - 103.80	58.67 (17.24)
60mm	33.00 - 131.40	65.02 (22.97)
70mm	23.60 - 139.40	72.11 (27.97)
Total	38.47 - 124.87	64.93 (20.50)

BMI Body Mass Index*; EDI-3* Eating Disorder Inventory; *DCQ* Dysmorphic Concern Questionnaire; *MAIA* Multidimensional Assessment of Interoceptive Awareness; *TEAQ* Touch Experiences and Attitudes Questionnaire; *SD* Standard Deviation.

Table 6.2.5.1.1 demonstrates the average (x, y, z) Talairach coordinates averaged across all participants for the vmPFC and Vertex and the average MNI coordinates for S1, which were the average coordinates used to localise the coil onto the scalp. All coordinates have been taken from that reported from the SofTaxic Neuronavigation system. All coordinates are originally reported in MNI space and have been converted to Talairach.

Table 6.2.5.1.2 Demonstrates the MNI coordinates for S1 and Talairach coordinates for vmPFC and Vertex averaged across all participants (*n= 18*) for each brain region (vmPFC, S1, and Vertex) for the localisation of the coil using the Softaxic Neuronavigation system.

	X	**Y**	**Z**
Brain Regions			
vmPFC	5.86	56.71	-10.57
S1	45.57	-27.71	71.86
Vertex	1.43	-42.14	68.43

vmPFC Ventro Medial Prefrontal Cortex; *S1* Primary Somatosensory Cortex

6.2.5.2 Vicarious ratings of self-directed touch

The 2-way within-subjects ANOVA of brain region (3 levels: vmPFC, S1 and Vertex) x Velocity (0 cm/s, 5 cm/s and 30 cm/s) of pleasantness ratings for oneself, revealed a significant main effect of brain region [F (2,34) = 3.770, p=.033, ηp^2 = .182, $BF_{inc\ 1}$= 1.938]. Significantly higher pleasantness ratings were provided for S1-cTBS (51.55 ± 3.84) compared to vertex-cTBS (45.80 ± 3.06, p = .037, BF_{10} = 26.046) and mPFC-cTBS (46.87 ± 3.28, p = .043, BF_{10} = 2.79). No evidence for a significant difference between mPFC-cTBS and the Vertex-cTBS was observed (p = .635, BF_{10} = .188).

There was also a significant main effect of velocity [F (2, 34) = 15.408, p <. 001, ηp^2 = .48, $BF10$ = 1116.5]. 6.5]. Touch to the self was greater for touch velocities of 5 cm/s (60.05 ± 5.13) compared to touch delivered at 0 cm/s (46.69 ± 2.84, p < .001, BF_{10} = 14606.3) and 30 cm/s velocities (37.48 ± 3.50, p < .001, BF_{10} = 1.035 x 10^{+8}). Furthermore, touch delivered at 0 cm/s velocity (46.69 ± 2.84) received greater ratings compared to that delivered at 30 cm/s (37.48 ± 3.50, p = .031, BF_{10} = 61.176).

Surprisingly, there was no significant 2- way interaction between brain region × velocity [F (4,68)= 0.503, p = .733, $\eta p2$ = 0.03, BF_{incl} = .083], with the Bayes factor analysis providing stronger evidence for no interaction between the two factors (see figure 6.2.5.2.1 for a visual breakdown of results).

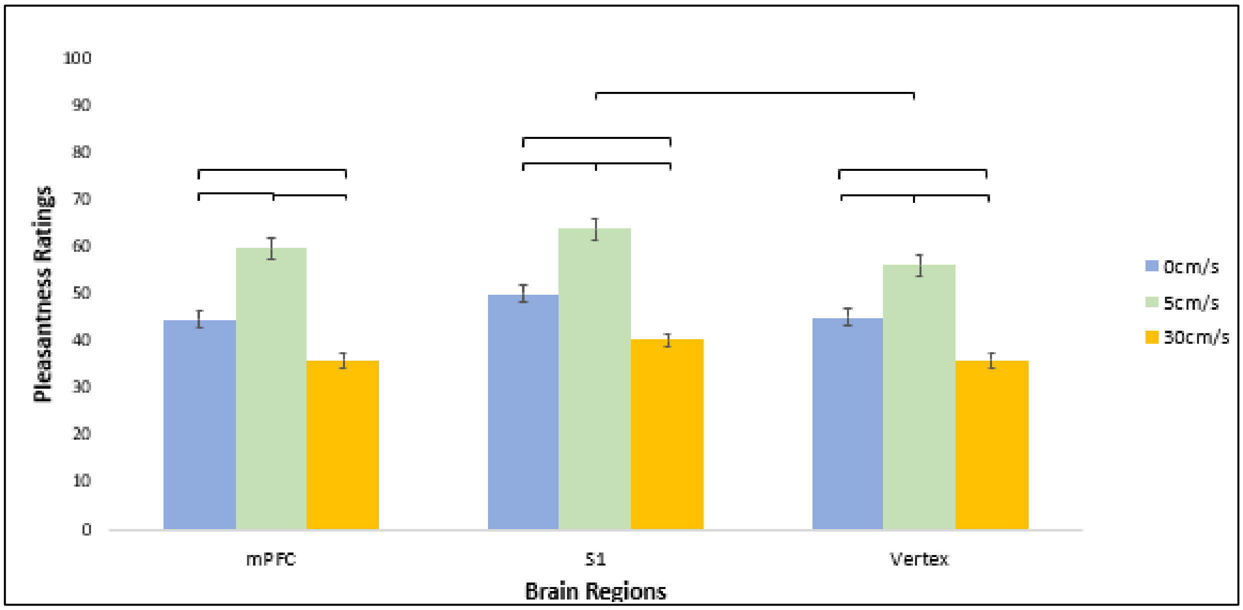

Figure 6.2.5.2.1 *Pleasantness ratings for each velocity, which have been collapsed across body sites, for each of the 3 brain regions (vmPFC, S1 and Vertex) for self-directed touch.*

We then conducted exploratory Pearson's Correlational analysis for self-directed touch separately considering the index (Brain Areas X-Vertex (delta effect)) for pleasantness ratings for S1-Vertex with EDI-3, MAIA, TEAQ, DCQ questionnaires and TET to understand if any effects from brain stimulation on pleasantness ratings correlates with scales specific to ED symptomatology. Results revealed a significant positive correlation with emotional awareness (r= .604, p= .008; see figure 6.2.5.2.2). Thus, participants with higher levels of emotional awareness rate they would like to receive touch more following inhibitory stimulation of the S1 than following vertex stimulation.

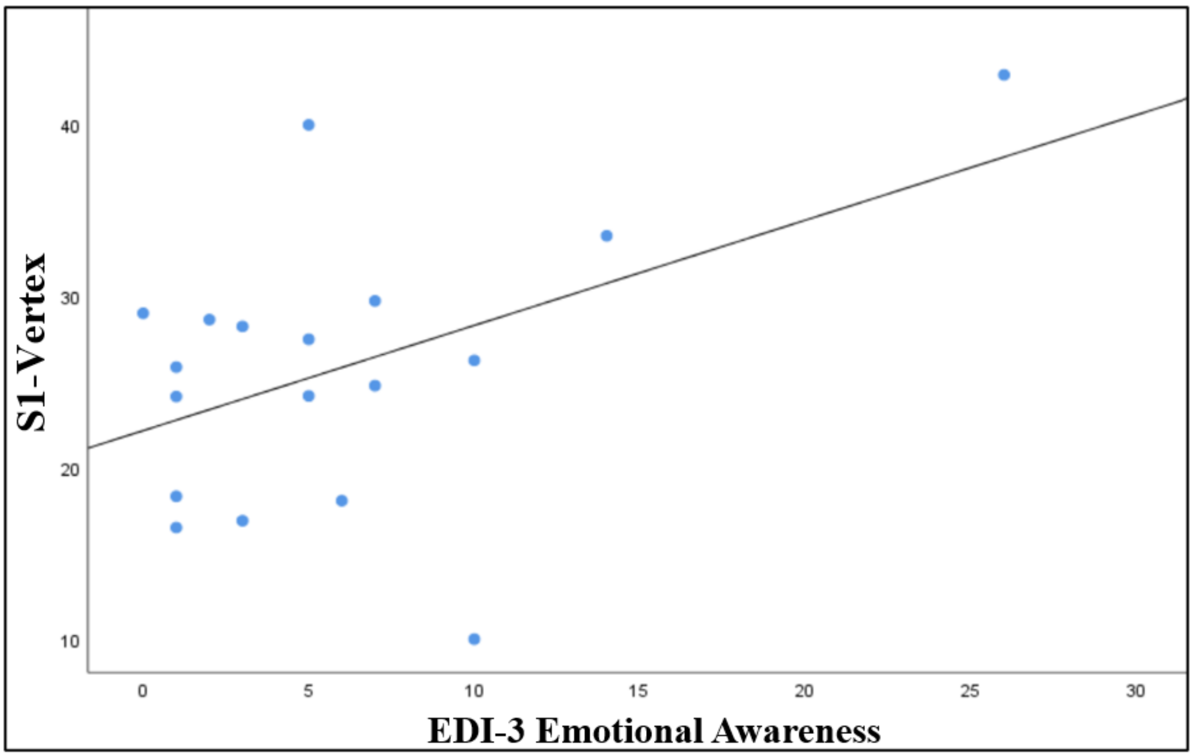

Figure 6.2.5.2.2 *Correlational analysis revealing a positive correlation between S1-Vertex and emotional awareness for other directed touch.*

In summary, regardless of cTBS to brain regions, CT-optimal velocity of 5 cm/s was always preferred when asked about touch to self, compared to CT non-optimal velocities such as 0 cm/s and 30 cm/s. Crucially, cTBS over S1 increased pleasantness ratings compared to vertex, cTBS to vmPFC did not significantly reduce pleasantness ratings regarding touch to the self (although Bayes Factor analysis suggested that compared to mPFC-cTBS, this effect was statistically inconclusive and therefore it remains unclear whether the effect of S1-cTBS was location-specific). Interestingly, this finding was also associated with evidence of a greater levels of emotional awareness (EDI-3). Finally, the increase in self-directed touch ratings after S1-cTBS was not CT-optimal touch specific, as also demonstrated by the Bayesian statistics which showed evidence for the absence of a selective effect of stimulation after cTBS, specifically for CT-optimal (slow) affective touch.

6.2.5.3 Vicarious ratings of other-directed touch

The 2-way within-subjects ANOVA of brain region (3 levels: vmPFC, S1 and Vertex) x Velocity (0 cm/s, 5 cm/s and 30 cm/s) of pleasantness ratings for another, revealed a significant main effect of brain region [F (2,34) = 4.384, p=.020, ηp^2 = .205, $BF_{inc\ l}$= 1.479]. cTBS-vmPFC (46.92 ± 2.32) significantly lowered pleasantness ratings compared to cTBS-Vertex (51.33 ± 2.72, p = .026, BF_{10} = 13.923) and cTBS-S1 (50.70 ± 2.04, p = 0.025, BF_{10} = 5.255). Importantly, cTBS over S1 (50.70 ± 2.04) did not significantly lower pleasantness ratings compared to Vertex-cTBS (51.33 ± 2.72, p = 0.701, BF_{10} = .163).

There was also a significant main effect of velocity [F (2, 34) = 22.803, p <. 001, ηp^2 = .57, BF_{10} = 1978.1]. Other-directed touch delivered at 5 cm/s (63.17 ± 4.06) was rated as significantly more pleasant compared to touch delivered at 0 cm/s (47.96 ± 2.02, p < 0.001, BF_{10} =7.463×10^{+9}). Furthermore, touch delivered to others at 0 cm/s (47.96 ± 2.02) was rated as significantly more pleasant compared to touch delivered at 30 cm/s (37.82 ± 2.84, p = 0.011, BF_{10} = 750.011). Similar to results obtained for the self-directed touch task, there was no significant 2-way interaction between brain region × velocity [F (4, 68) = .768, p = .550, $\eta p2$ = .04, BF_{10} = .324, with the Bayes factor analysis providing stronger evidence in favour of no interaction between the two factors (see figure 6.2.5.3.1).

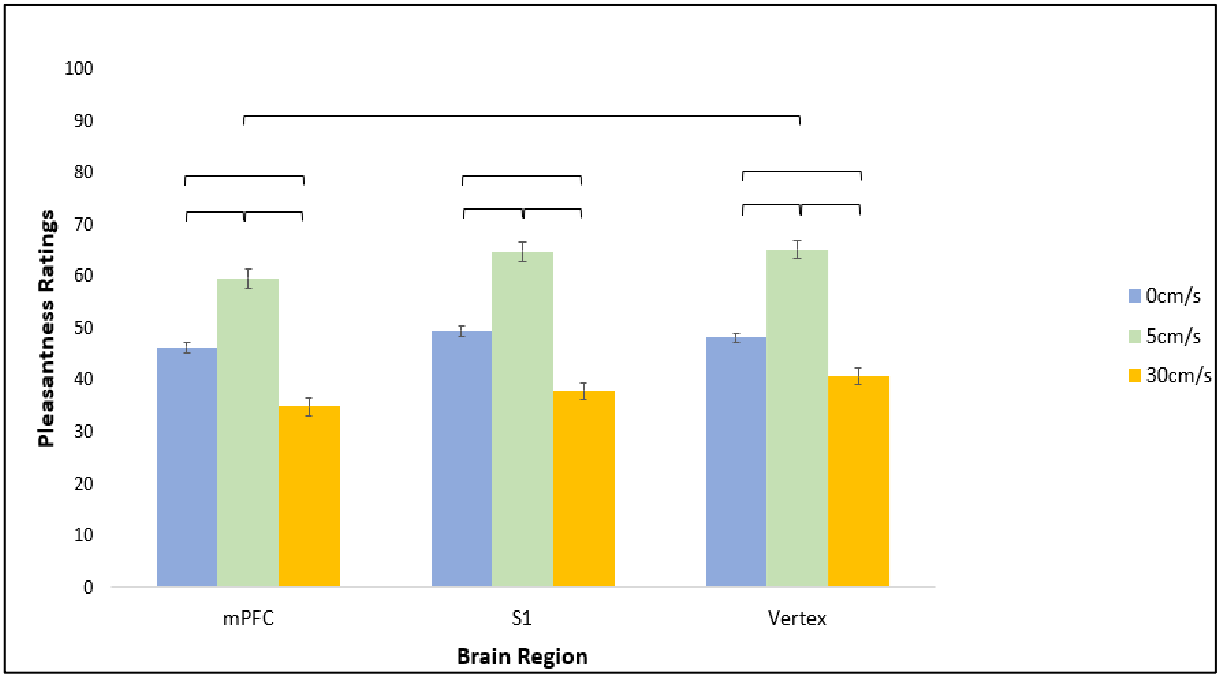

Figure 6.2.5.3.1 *Pleasantness ratings for each velocity, which have been collapsed across body sites, for each of the 3 brain regions (vmPFC, S1 and Vertex) for other-directed touch.*

Exploratory Pearson's Correlational analysis were conducted for other-directed touch separately considering the index (Brain Areas X-Vertex (delta effect)) for pleasantness ratings for mPFC-Vertex with variables from EDI-3, MAIA, TEAQ, DCQ questionnaires and TET to understand if any effects from brain stimulation on pleasantness ratings correlates with scales specific to ED symptomatology. Results revealed no significant correlations with mPFC-Vertex and any subscales (*all ps >.102*).

In summary, regardless of cTBS to brain regions, CT-optimal velocity of 5cm/s was always preferred regarding touch for another person compared to non-optimal velocities of 0 cm/s and 30 cm/s. cTBS delivered over the vmPFC significantly decreased pleasantness ratings compared to cTBS delivered over vertex and S1, in which a lack of differences in pleasantness ratings was observed. Like the result obtained for self-directed touch, the lack of a significant 2-way interaction of brain region and velocities suggests that the effects of stimulation over mPFC is not specific for CT-optimal touch. This result was also confirmed by the Bayesian statistics which showed evidence for the absence of a selective interferential effect of cTBS, specifically for CT-optimal (slow) affective touch.

6.2.6 Discussion

This was the first study to investigate whether inhibiting the vmPFC and S1 by cTBS is causative of a change in touch pleasantness ratings for self-directed and other-directed social touch and whether this is associated with ED symptomatology. To achieve this, we recruited healthy females with no current or previous AN diagnosis to establish the involvement of these brain regions in vicarious affective touch responses. It was important to recruit healthy females with no impairments in these regions, to understand if there is a connection with a reduction in the functioning of these brain areas and EDs traits. We considered interoceptive awareness, dysmorphic concerns and touch experiences and attitudes as factors which could impact pleasantness ratings for social touch, as these are key factors in the aetiology and development of EDs (Beilharz et al., 2019; Kaye et al., 2009; Nandrino et al., 2012; Strigo et al., 2013).

In overview, results from this study demonstrated that cTBS of S1, compared to cTBS of the Vertex resulted in greater pleasantness evaluations for self-directed touch, this was not specific to the CT-velocity of that touch. Therefore, the findings from previous research suggests that S1 is involved in the visual processing of touch directed towards the self.

The findings from this current study show that inhibiting S1 resulted in participants demonstrating a greater willingness to receive social touch for the self, compared to Vertex. This findings suggest that S1 may have a key role in the visual processing of self-directed touch (regardless of CT touch optimality). However, based on the analysis of the Bayes Factor, it’s difficult to ascertain if increases in wanting responses for self-directed touch was specifically related to S1, as the effect is small.

Nonetheless, this finding supports previous research suggesting that the right S1 is involved in visuo-tactile mirroring mechanisms which are crucial for evaluating one's own experience of touch, whilst observing another receiving that touch (Blakemore et al., 2005; Keysers et al., 2004). In addition, not only is S1 involved in the visual processing of touch but is believed to be involved in the encoding of the shared social or affective tactile experiences and qualities of another, independently from their positive or negative valence (see also Rigato et al, 2019). This shared experience would allow for the remapping of the other tactile experiences for the self (Adler et al., 2016; Blakemore et al., 2005, Bufalari et al., 2007, Deschrijver et al., 2016; Ebisch et al., 2008, Keysers et al., 2004, Pihko et al., 2010, Schaefer et al., 2009, Wood et al., 2010). Based on this assumption, it was expected that upon perturbation of S1, it would be no longer possible to experience the positive value of the touch of another. As a result of this, one would perceive touch as less pleasant, which should lead to a decrease the willingness to be touched. On the contrary, this was not to be the case, as pleasantness ratings increased as opposed to decrease. One possible interpretation for this finding could be a explained by the predictive coding framework (Huang & Rao, 2011; Millidge et al., 2022), in which the perception of a given action is reliant upon noise of the incoming sensory signals, in order to continuously produce and revise a mental model of the observed action (Beal et al., 2003). The brain serves as a predictive machine and uses this generated model to generate predictions of sensory input. The brain is then able to compare this to actual incoming sensory signals, in order to minimise prediction errors, which is the difference between predictions and the actual signal (Huang & Rao, 2011; Millidge et al., 2022). The brain then formulates Bayesian-optimal predictions (i.e., apply probabilities) of future scenarios which must be continuously updated, and earlier beliefs revised through the feedback of new sensory information. This procedure requires the comparison of both bottom-up and top-down predictions and these must be weighted based on their reliability and uncertainty (Doya, 2007; Friston, 2010; Knill & Pouget, 2004; Millidge et al., 2022; O'Reilly et al., 2012). These predictions not only occur in relation to situations and events, but predictions are also generated in response to internal bodily states (Seth & Friston, 2016). Therefore, it could be argued that we add noise to the Somatosenory signal when inhibiting S1 in the current study. This could have resulted in more prediction errors, as these incoming signals would have been categorised as unreliable and the brain may have used prior beliefs and not updated beliefs to make judgements for pleasantness of touch. Hence, the participants may have known that the touch they were observing was a pleasant touch experience in the past and so would have greater willingness to be touched in the same way, as opposed to updating their beliefs and evaluating the touch as less pleasant. Alternatively, in line with the TMS study of Case et al. (2016) which shows increased ratings of brushing intensity after inhibitory TMS to S1, it might be that cTBS over S1 causes a reduced sensory discrimination thus increasing perception of touch intensity (regardless of CT-optimal touch).

Furthermore, the inhibition of S1 did not lead to a reduction in pleasantness ratings for CT-optimal touch to self. Therefore, implying that the processing of CT-optimal touch to the self occurs outside of S1. It could be that S1 may be involved in the processing of all forms of affective touch regardless of the speed/velocity of the touch. Overall, results suggest that S1 is not explicitly involved in affective touch processing and may be a network more directly involved in the visual network associated with body image disturbances in AN (Favaro et al., 2012), given that disruption to this region does not impede with pleasantness ratings for self-directed touch. Thus, as found previously by Olausson et al. (2002), a reduction is S1 functioning does not result in reduced pleasantness of touch and offering support for the suggestion for this region to be involved in touch discrimination and visual aspects of affective touch (Cohen et al., 1991). Moreover, pleasantness ratings for cTBS S1 for self-directed touch revealed that the higher the willingness to be touched, regardless of CT-optimal touch, the higher the levels of emotional awareness (Adolphs et al., 2000). A possible explanation could be that given that the right somatosensory cortex plays a role in visual emotion recognition (Adolphs et al., 2000), one would expect that as pleasantness ratings increase so would awareness of emotions. In addition, this region also shares connectivity with the amygdala, a region largely involved in emotion regulation and also shares connections to the Insula (Augustine, 1996; Höistad et al., 2008). Therefore, in the current study, higher pleasantness ratings for cTBS S1 should be associated with greater levels of emotional awareness, given the region's involvement in this process. However, the use of Interoceptive deficits (EDI-3) as a measure is limited in the assessment of interoception i.e., somatic awareness and is more explicitly related to emotional awareness (Eshkevari, Rieger, Musiat, & Treasure, 2014). A study conducted by Adler and Gillmeister (2019) revealed that more accurate interoceptive abilities in sustaining and controlling attention to bodily signals, was associated with the somatosensory cortices having better representations of observed touch (Adler & Gillmeister, 2019). Therefore, future studies should incorporate a measure which investigates somatic awareness as opposed to focusing on emotional awareness in order to provide more conclusive correlational analysis between interoception and cTBS S1.

Also, given that social cognition is key in the attribution of mental states for the self (Frith & Frith, 1999; Schurz et al., 2014), one would expect a reduction in pleasantness ratings to also be present due to cTBS over vmPFC for self-directed touch. However, this was not the case for the current study, cTBS delivered over vmPFC did not result in a reduction in pleasantness ratings when making inferences for self. A possible explanation could be that other regions in the mPFC, not the ventro-medial region, such as the posterior cingulate cortex or the precuneus could be involved in self-knowledge (Northoff et al., 2006; Northoff & Bermpohl, 2004).

Nevertheless, as anticipated, inhibition of the vmPFC resulted in the reduction in pleasantness ratings when making inferences regarding someone else receiving social touch, as the mPFC is a key node of the 'social brain' (Amodio & Firth, 2006; Frith & Frith, 2003, 2006; Mar, 2011; Sperduti et al., 2011). The mPFC is well known for its involvement in theory of mind, mindreading and mentalising abilities (for reviews see Mar, 2011; Sperduti et al., 2011), and is implicated in inferring other people's intentions and mental states as well as attributing emotional states to others (Mar, 2011; Schurz et al., 2014; Sperduti et al., 2011). Previous evidence suggests that during gentle touch to the arm compared to palm, activation in right mPFC/dACC showed greater connectivity with left insula and amygdala (Gordon et al 2013), which may represent a coding of the social relevance and social reward of the tactile stimuli. Therefore, in the current investigation, when asked to make judgement of someone else, one would expect the mPFC to be largely involved in this process. Disruption to this region, as found in the current study, should demonstrate a reduction in pleasantness ratings, given the more inaccuracies of not being able to infer and attribute pleasantness of touch for someone else, due to a reduced functioning from inhibiting the vmPFC (Stuss et al., 2001). Nevertheless, the inhibition of the vmPFC was not specific to a reduction in pleasantness ratings for CT-optimal touch for another, which was also confirmed by the Bayes factor analysis, which was in favour of the null hypothesis. Therefore, implying that this region is involved in the processing of social touch when viewing someone else receiving touch and that the processing of CT-optimal touch occurs outside of vmPFC. In addition, no correlations were observed between vmPFC and EDs traits. It was expected there to be negative correlations associated with cTBS delivered over vmPFC and emotional awareness, given the involvement of this region in this process (Lane et al., 1998; LeDoux, 2000; Cohen et al., 2001; Adolphs, 2002; Ochsner and Gross, 2005; Phelps, 2006; Duncan and Barrett, 2007; Lieberman, 2007). Overall, findings support a possible link in a dysfunction in the vmPFC and atypical responses to affective touch in individuals with AN (Koechlin, 2011) particularly for mentalising abilities and inferring states of another, which could account for social impairments in AN (de Sampaio et al., 2013; Schmidt et al., 1995; Godart et al., 2004; Russell et al., 2009).

Although the study offered insight into the role of the vmPFC in other-directed touch, and that both S1 and vmPFC have dissociative roles depending on whether touch is for self or another person, several limitations have been identified. Firstly, the videos used in the current study do not contain any contextual information such as visual or auditory cues of the touch provider, which are key in the understanding of pleasantness of touch (Macaluso & Driver, 2001; Taylor-Clarke et al., 2002). Also the motivation and mood of the touch provider (Kalaska, 1994; Montoya & Sitges, 2006; Triscoli et al., 2014), which are important for the understanding of whether the touch is positive or negative (Ellingsen et al., 2016). Furthermore, it would be important to outline the relationship between the touch giver and receiver in the videos. This would allow for the control of individual differences in who the individual is imagining receiving this touch from, as touch from different relationships is evaluated differently. In providing this information, this would allow for participants to be able to fully embody the observed touch and be able to imagine a scenario where they are in receipt of touch from a specific individual. For example, romantic touch from a partner or touch received from a loved one is perceived as more pleasant than from touch from a stranger. Furthermore, suggesting touch to be given from a stranger may impede negatively with their responses (Kreuder et al., 2017; Suvilehto et al., 2015). Therefore, contextual factors relating to touch pleasantness should be considered, which is the case for study 3 (see Chapter 5), in which contextual information such as the touch giver is controlled for when assessing responses to receiving touch to specific body regions. It may also be useful in the future to assess levels of empathy (Peled-Avron et al., 2016), given this study involves mentalising abilities and also to assess participants mood at the time of participation (Snaith et al., 1995), given that mood may impacts ratings of affective touch i.e., low mood leads to lower pleasantness to touch.

Lastly, in relation to the touch videos, it should be noted that all touch from male to female was delivered using the right hand of the male. Given that disruption to both vmPFC and S1 was on the right, it would be beneficial in the future to use a left hand delivering the touch as each hemisphere controls the opposite side of the body i.e., the right hemisphere controls the left side of the body (Corballis, 2014). Therefore, disruption to the right hemisphere would cause interference with the processing of movement if the left hand of the male was in the social touch videos. The use of the male delivering touch with a right hand and disrupting the right hemisphere of the vmPFC and S1 could have influenced the results from this study.

Furthermore, interhemispheric compensation due to long lasting effects of TMS might happen to due to plasticity of the brain, given that only one side of the brain was inhibited for each brain region and the left hemisphere may have compensated for the reduced functioning in areas on the right (Sack et al., 2005). Therefore, in future studies it would be useful to combine fMRI and TMS, to be certain that TMS has in fact inhibited these regions and that there are clear differences in functioning prior to and proceeding after TMS. This will ensure inhibition has occurred to the desired regions and will make certain that the left hemisphere has not compensated for inhibition of the right hemisphere.

In addition, in order to ensure there was not interhemispheric compensation (sack et al., 2005), in the future it would be beneficial to disrupt both hemispheres of the vmPFC and S1. This could be done using the same inhibitory theta-burst protocol in this study

(Goldsworthy et al., 2012) but with the addition of an additional figure of eight coil (one on each hemisphere) as demonstrated in the study of Vassiliadis et al. (2018). In inhibiting both regions, this would ensure that the left hemisphere of S1, could not compensate and influence vicarious touch responses when the right hemisphere is disrupted.

Furthermore, as the activation of S1 is reliant on the level to which the individual resembles the observed body part as their own (Rigato et al., 2019), it could also be useful to ensure participants fully embody the touch they are viewing, to use Virtual Reality which is a computer-generated simulation of a 3D virtual world. This form of technology has been used previously and has shown to be successful in bodily ownership (Bertrand et al., 2018).

Furthermore, given that results from both tasks suggest that CT-optimal touch is encoded outside of S1 and mPFC, it would be useful to inhibit regions with TMS to examine CT touch with other regions who share connectivity to the Insula Cortex such as the orbitofrontal cortex (OFC) (Rolls, 2004) and anterior cingulate cortex (ACC) (Lindgren et al., 2012). The Insula Cortex is difficult to examine given that it is subcortical, even with the use of H-Coil deep stimulation and it is unclear if this stimulation effects surrounding regions and reaches the Insula with enough intensity (Knyahnytska et al., 2019; Lee et al., 2020).

Most importantly, if S1-cTBS improves willingness to receive self-directed touch which was shown to be atypical in women with AN and RAN in study 2, then using the cTBS protocol targeting S1 could be used to improve individuals with AN responses to self-directed touch. Due to the complexity of targeting the Insula (Knyahnytska et al., 2019; Lee et al., 2020), S1 could be a useful alternative target region for future non-pharmacological interventions, which could help improve overall self-directed touch processing in patients regardless of the CT-optimality. The same protocol (theta-burst stimulation) could be used across various sessions, given that touch wanting significantly increased after one session of cTBS-S1. This could also be conducted bilaterally, in order to ensure the functioning of both hemispheres in S1 are improved, given the improvement bilateral TMS has shown in other treatments for other disorders (Summers et al., 2007).

6.2.6.1 Conclusions

Overall, results suggest that vmPFC has some involvement in the observation of someone else receiving touch. This could occur because of participants being more able to embody the experience of touch and making inferences about the rewarding value of the touch for others. Inhibition of this region suggested that participants failed to make inferences about others' intentions and mental states i.e., their ability to attribute emotional states to others decreased specifically and compared to cTBS delivered over S1 and vertex. As a result, participants evaluated touch for another as less pleasant. Therefore, it would be interesting in the future to investigate an association between impairments in the vmPFC and pleasantness ratings of touch in individuals with AN, particularly when taking the perspective of another (de Sampaio et al., 2013; Schmidt et al., 1995; Godart et al., 2004; Russell et al., 2009). Inhibition of S1 increased evaluation of vicarious touch and more wanting to receive touch. A possible explanation could be that in line with the TMS study of Case et al. (2016) intensity of touch discrimination is impaired with disruption to this region, as opposed to pleasantness of touch. Alternatively, within the framework of predictive coding, prior beliefs regarding touch pleasantness were used to guide interpretation due to too much noise interference in sensory input. Nevertheless, results from both tasks suggest that CT-optimal touch seems to be encoded outside of S1 and mPFC, given the lack of interaction with velocity in both self vs. other-directed touch. Therefore, future studies would be useful to investigate other regions which may be involved in atypical affective touch processing in AN, such as the orbitofrontal cortex (OFC) (Rolls, 2004) and anterior cingulate cortex (ACC) (Lindgren et al., 2012).

Most importantly, results from the current study offer insight for a valuable future non-pharmacological intervention targeting S1 for self-directed touch, shown to be atypical in both women with AN and RAN (study 2, Chapter 4), given that cTBS to this region resulted in greater wanting for touch.

Chapter 7
General Discussion

7.1 Introduction

As outlined in Chapter 1.3, the aetiology surrounding AN remains unknown due to the complexity of this condition and this requires further investigation. Based on this, the main aim of this PhD project was to offer further understanding into the aetiology of this condition, by investigating whether individuals with AN display atypical self and other-directed vicarious social touch responses and to understand the neural underpinnings potentially surrounding these evaluations. In order to achieve this, behavioural and psychophysiological methods were utilised. In particular, as outlined in Chapters 3 and 4 (Studies 1 and 2), behavioural methods were used, specifically the touch videos detailed in Trotter et al. (2018a). In Chapter 5 (Study 3), a newly developed and novel mobile application was used to assess soothing and unpleasantness of vicarious social self-directed touch from a loved one or an acquaintance in individuals with high and low levels of BIDs. In Chapter 6 (Study 4), a psychophysiological method was incorporated to understand what the neural underpinnings are using neuro-navigated offline cTBS TMS, as outlined in Pollatos et al. (2016) and Willacker et al. (2020) for self and other-directed social touch. The right vmPFC and S1 were the regions targeted, with an inhibitory protocol employed.

7.1.1 Re-cap of aims in each study

1. The first aim, which was addressed in study 1 (Chapter 3) was to investigate through two different tasks, whether third-party vicarious ratings of social touch delivered at CT-optimal vs. CT non-optimal velocities differed in women reporting low and high EDs risk symptoms.

   Furthermore, this investigation aimed to examine whether individual differences in levels of eating disorder symptoms, as well as dysmorphic appearance concerns, body awareness and social touch experience may impact participants' pleasantness ratings for specific body sites.

2. The second aim, which was adhered to in study 2 (Chapter 4), was to investigate whether third-party vicarious ratings of affective touch provided at CT-optimal vs. CT non-optimal velocities differed in women reporting a current diagnosis of AN compared to HCs. Importantly, we also recruited women with recovered AN (RAN) individuals to examine whether the differences in self- vs. other-directed third-party ratings, may also apply to recovered patients in comparison to HCs. Furthermore, we wanted to investigate whether body awareness and social touch experiences may be significant predictors of vicarious social touch responses when touch is self-directed compared to other-directed in both women with AN and RAN.
3. Study 3 (Chapter 5) aimed to assess the imagined perception of soothing and unpleasantness responses to self-directed social touch in real life affective scenarios in individuals with high and low levels of BIDs. Furthermore, it was anticipated that for the high levels of BIDs group, greater levels of unpleasantness to touch, regardless of whether this is from a loved one or an acquaintance, was associated with higher levels of dysmorphic concerns and greater interoceptive deficits.
4. Finally, Study 4 (Chapter 6) aimed to establish whether inhibitory Transcranial Magnetic Stimulation (rTMS) over the right S1 and vmPFC is causative of atypical vicarious affective touch responses for self and other-directed touch, in relation to ED symptomatology. Furthermore, this investigation aimed to examine the links with pleasantness ratings of affective touch and eating disorder traits such as interoceptive deficits and body image concerns (Crucianelli et al., 2016; Davidovic et al., 2018; Kaye, Fudge, & Paulus, 2009; Pollatos et al., 2008) and body image misperception (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016; Perez, Coley, Crandall, Di Lorenzo, & Bravender, 2013).

In this final chapter of this Thesis, results from all four studies are summarised and compared against previous research outlined in Chapter 1. The findings from this PhD project are discussed with regards to their contribution towards vicarious responses to self- and other-directed social touch in women with AN, RAN and subclinical EDs populations. Furthermore, these findings are outlined in response to their contribution towards the brain regions involved in vicarious social touch in subclinical populations. In addition, methodological limitations and directions for future studies are outlined.

7.2 Overview of findings

Interestingly, the findings from this PhD project revealed that no changes to affective touch processing occurs prior to the onset of AN (Study 1, Chapter 3). Both women with high EDs risk and low EDs risk in study 1 did not differ in their third-party ratings of vicarious self-directed and other-directed social touch. Instead, results have revealed that atypical responses to vicarious social touch occurs prior to the onset of AN and manifests post recovery from AN, specifically for self-directed touch, with both clinical groups rating this touch as less pleasant than HCs (Study 2, Chapter 4). The responses to receiving self-directed social touch is dependent upon the relationship shared between the touch provider and the touch receiver (Study 3, Chapter 5). Furthermore, another important finding from this PhD highlighted that both S1 and the vmPFC have distinctive roles in social touch processing, with S1 largely involved in self-directed touch and the vmPFC being associated with other-directed touch (Study 4, Chapter 6) (For a breakdown of findings, see Figure 7.2.1).

In relation to the above findings, it could be suggested that as altered responses to self-directed social touch occurred for both AN and RAN for vicarious social touch, as outlined by Tagini et al. (2023) and Crucianelli et al. (2021), it could be argued that the atypical responses to observed social touch is more related to deficits in top-down influences i.e., brain responses as opposed to bottom up i.e., impairments in the CT afferent system. Therefore, given that CTs only respond when actual touch is provided (Tagini et al., 2023), these atypical responses to self-directed vicarious touch in both AN and RAN could be more cognitively associated with social regions. In further support, Morrison et al. (2011) suggested that the brain may be accustomed to perceive CT-specific components of touch when observing another receiving this type of touch. Thus, the involvement of CTs is may not necessary for the observation of another receiving touch.

Nonetheless, it is difficult to make solid conclusions which rule out the involvement of CTs in atypical responses to social touch in AN, as unlike in Tagini et al. (2023), this PhD project did not incorporate a real touch element. Therefore, comparisons could not be made between real and vicarious social touch responses and the necessity of CTs in both types of touch. However, this was not possible at the time of testing.

Overall, given that atypical responses to social touch in women with and recovered from AN occurs in relation to self-directed touch and that this could be influenced more by top-down influence, this result offers the potential for future pilot studies to be developed. This intervention could incorporate both TMS in order to target regions involved in atypical responses to self-directed social touch in individuals with AN. Also, this intervention should be provided to women who are in recovery from AN to help prevent this trait from reoccurring.

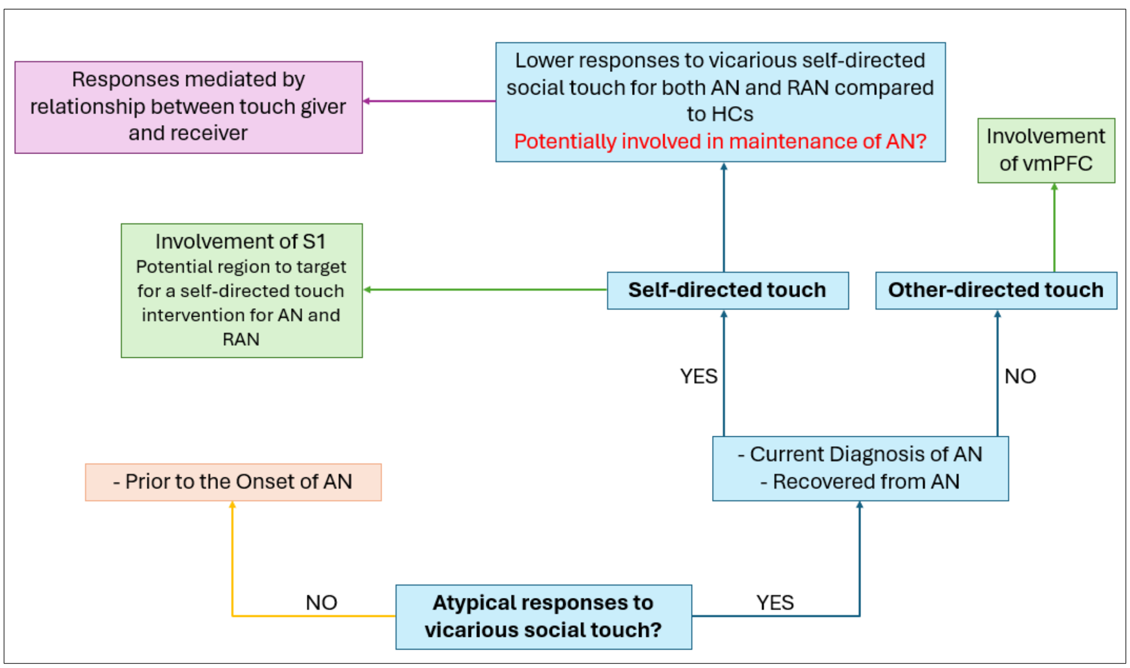

Figure 7.2.1 *A model which provides an overview of the findings from the current PhD project, specifically demonstrating that atypical responses to vicarious social touch are not apparent prior to the onset of AN, but occur after the onset of AN and post-recovery. The green areas highlight the brain regions involved in self-directed and other-directed touch and the purple area provides important information regarding the involvement of relationship in social touch responses.*

Specifically, in Chapter 3 (Study 1), responses to vicarious social touch in women with high and low EDs risk were tested. Specifically, we investigated whether third-party vicarious ratings of social touch delivered at CT-optimal vs. CT non-optimal velocities differ in women reporting low and high EDs risk symptoms. We achieved this by administering social touch videos (Trotter et al., 2018a), which depicted interpersonal touch delivered from a male to a female at both CT-optimal and non-CT optimal velocities (0 cm/s, 5 cm/s and 30 cm/s), to various body regions such as the back, ventral forearm, upper arm, cheek, and palm (Trotter et al., 2018a). The results from this study revealed there to be no group differences in vicarious responses to touch for both self-directed and other-directed touch. Unlike in Walker et al. (2017), both groups displayed atypical ratings for CT-optimal touch and these ratings varied across body sites, with CT-optimal touch being rated as most pleasant for all sites excluding the upper arm and back. Pleasantness of touch was also observed in the palm, this region has been under dispute regarding pleasantness responses, with controversy as to whether this glabrous region lacks CTs or whether CTs are in fact present (Essick et al., 2010; Morrison, 2016; Watkins et al., 2021). In addition, it was revealed that eating disorder traits and specific facets of interoceptive awareness accounted for touch ratings for specific body sites only. Individual differences in interoceptive awareness could have also influenced results as some individuals may vary in their ability to be aware of various bodily sensations. For example, some individuals may be accurate in detecting cardiac signals but less able to be aware of sensations relating to respiratory or gastric signals (Murphy et al., 2019). These individual differences in interoceptive awareness could account for why pleasantness ratings for specific body sites only was associated with interoceptive awareness. Overall, findings from this suggest that third-party ratings of touch pleasantness do not differ between neurotypical females and those at heightened EDs risk and that this could have been accounted for by individual differences in interoceptive awareness.

In Chapter 4 (Study 2), as findings from study 1 did not reveal any differences in vicarious ratings of social touch in women reporting differing levels of risk of an eating disorder, we wanted to explore if these differences occur in women with a clinical diagnosis of AN, recovered from AN, compared to healthy controls. Specifically, we investigated whether third-party social touch vicarious ratings of different body sites at CT-optimal vs. non-CT optimal velocities differed in women with and recovered from AN and HCs. Individuals with a self-reported diagnosis of AN, RAN and HCs provided pleasantness ratings for two different tasks designed to probe expectations of how touch is perceived by self (self-directed touch) vs. others (other-directed touch), using the same videos as in study 1. Findings revealed that both clinical groups, compared to HCs, did not differ in their pleasantness ratings to touch for another but when evaluating touch for self, both clinical groups rated CT-optimal touch as less pleasant than HCs. Additionally, third-party ratings of touch pleasantness for another individual did not differ regardless of eating disorder diagnosis. Hence, altered responses to affective touch in women with AN and RAN appear to be self-specific and are intact when making judgements of touch for someone else. Furthermore, ED traits, interoceptive awareness and social touch experiences were associated with overall touch pleasantness particularly for women with and recovered from AN. These findings suggest that women with AN and RAN demonstrate an atypical pleasantness response to vicarious affective touch involving self, but not when making judgement for others.

Given that in study 2 (Chapter 4), individuals with AN displayed atypical responses to self-directed vicarious social touch, in Chapter 5 (Study 3), we assessed soothing and unpleasantness of imagined social touch to various body regions (intimate and social body regions) from a loved one compared to an acquaintance, in individuals with high and low body image disturbances. In order to measure this, participants used the Virtual Touch app to interact with a 3D avatar and using a heatmap scale, indicated the body regions they found to be soothing or unpleasant to be touched from a loved one and an acquaintance. The results from this study revealed that soothing responses to imagined social touch is greatly influenced by social context. Specifically, touch from a familiar person was evaluated as soothing compared to when this is given from an acquaintance, which was rated as unpleasant (Suvilehto et al., 2015, 2019). This was the case for both high and low levels of BIDs, who did not demonstrate any differences in their evaluation of touch from both a loved one and an acquaintance. Furthermore, both groups demonstrated unpleasant responses to intimate regions and soothing responses to social regions.

Furthermore, based on the findings from study 2 and 3, in Chapter 6 (Study 4), we investigated whether inhibition of the right vmPFC and S1 is causative of atypical affective touch responses for self-directed and other-directed touch and if this is associated with reduced interoceptive awareness and ED symptomatology in a group of healthy women. This was achieved through participants receiving offline inhibitory continuous theta-burst stimulation (cTBS) over the right vmPFC, S1 and Vertex before providing third-party ratings of touch pleasantness using the videos also presented in studies 1 and 2 (Trotter et al., 2018). It was revealed that inhibiting S1 resulted in participants displaying a greater willingness to receive social touch when directed towards the self, compared to the Vertex condition. These findings offered support for the previous assumption that S1 is largely involved in the mirroring mechanism associated with observing and evaluating touch (Blakemore et al., 2005; Keysers et al., 2004). Given the large involvement of the vmPFC in social cognition (Amodio & Firth, 2006; Sperduti et al., 2011), as expected, inhibiting the vmPFC resulted in a reduction in pleasantness ratings when making judgements for someone else, but inhibition of this region did not have any impacts on pleasantness ratings for self-directed touch. It is important to note that these results outline the distinctive involvement of S1 and vmPFC in self-directed and other-directed vicarious social touch responses, with S1 being involved in self-directed touch and the vmPFC being involved in other-directed touch.

7.3 Interpretation of findings

7.3.1 Vicarious ratings of social touch in women with high and low eating disorder risk

As discussed in Chapter 1, to date, only a small number of studies which have investigated affective touch processing in high EDs risk, compared to healthy populations not at risk (Carey et al., 2019; 2021; Cazzato et al., 2021). Affective touch is typically evaluated as pleasant in healthy populations but is perceived as less pleasant in several clinical populations (Keizer et al., 2022), in particular in eating disorders such as AN and BN (Bellard et al. 2022; Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018; Tagini et al., 2023).

With regards to atypical responses to affective touch, there is no evidence of abnormal processing of vicarious affective touch compared to real touch responses. Based on the findings of Walker et al. (2017), it was expected that all body regions, excluding the palm would be rated as most pleasant for CT-optimal touch. However, unexpectedly, the results from study 1 demonstrated that responses to affective touch was dependent on the body regions, with CT-optimal touch being rated as the most pleasant for all sites excluding the upper arm and back. This was also present for the palm, which could be due to the evidence for CT innervation in this glabrous region (Essick et al., 2010; Watkins et al., 2021). The palm has been under controversy regarding the presence of CTs. This could be due to the fact that this region is frequently touched from a loved one such as a partner (Gulledge et al., 2003). It could therefore be argued that in addition to CT-innervated regions which are innately pleasant, touch to glabrous regions such as the palm may be evaluated as pleasant due to a learned response (Löken et al., 2011; Pawling et al., 2017). Therefore, as half of the sample in this investigation reported being in a romantic relationship, these individuals may be subject to frequent experiences of touch to the palm and have learned over time that touch to this region is pleasant.

Furthermore, we expected that there would be group differences between high risk and low EDs risk groups, with the high EDs risk group demonstrating atypical responses to touch, similar to individuals with AN and BN (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021; Davidovic et al., 2018; Bellard et al. 2022). We anticipated individuals with high EDs risk would also show evidence of touch avoidance and negative responses to touch (Zucker et al., 2013). Also, that the high EDs risk group would use these negative evaluations of touch to the self when making judgements for touch for another person (other-directed touch). Specifically, that the high EDs risk group would rate touch for another as more unpleasant than the low EDs risk group (de Sampaio et al., 2013; Gál et al., 2011; Hamatani et al., 2016; Russell et al., 2009; Tchanturia et al., 2018; Zucker et al., 2007). Surprisingly, the findings from this study demonstrated no clear differences between groups for ratings of touch across body sites, for both self and other-directed touch. An important main explanation for this finding could be that women in this sample did not have a formal diagnosis of an eating disorder and were more representative of a healthy population regardless of their risk. These women may have scored highly on the EDI-3 and demonstrated body image concerns like women with EDs, as body image concerns are also commonly reported in the general population (Bellard et al., 2020).

7.3.2 Vicarious ratings of social touch in women with AN and recovered from AN

As outlined in Chapter 1, atypical responses to affective touch occur in individuals with AN. These individuals rate this type of touch as unpleasant, compared to healthy populations, who evaluate affective touch as pleasant (Crucianelli et al., 2016, 2021; Davidovic et al., 2018). Atypical responses to affective touch have been found to still occur post recovery from AN when compared to healthy controls (Bischoff-Grethe et al., 2018).

It was revealed in study 2 (Chapter 4) that both women with AN and RAN rated CT-optimal touch as significantly less pleasant than HCs. This finding supports results obtained from Crucianelli et al. (2016) who also found that individuals with AN rated CT-optimal touch as less pleasant than HCs. Furthermore, the findings from study 2 also support Davidovic et al. (2018), who also found that individuals with AN rated affective touch as less pleasant compared to healthy populations. Similarly to Crucianelli et al. (2016)' study, study 2 also revealed that CT non-optimal velocities were not rated as significantly less pleasant for both women with AN and RAN compared to HCs. Nonetheless, Crucianelli et al. (2021) found that differences in affective touch ratings occurred when this touch was CT-non optimal, with CT-non optimal touch being rated as significantly less pleasant for people with RAN than HCs. This highlights the importance, that both women with AN and RAN have similar responses to affective touch and that even post recovery, these atypical responses remain. This finding only partially supports the aim that both women with AN and RAN differed in their third-party vicarious ratings of affective touch provided at CT-optimal vs. CT non-optimal velocities, given than this was only evident for CT-optimal touch and no differences were apparent for CT-non optimal touch.

Furthermore, Zucker et al. (2013) outlines that women with AN display enhanced negative sensitivity to sensory experiences such as touch and this could be an explanation as to why AN display unpleasant responses to receiving social affective touch. This negative sensitivity to receiving touch is coupled with heightened levels of anxiety due to severe discomfort (Arcelus et al., 2014). This explanation was supported by the findings in study 2 (Chapter 4), in that regardless of the velocity of touch, women with AN and RAN displayed atypical responses to affective touch when touch was directed towards the self and this explanation could account for the findings being specifically for self-directed touch. As proposed by Crucianelli et al. (2021), these findings from the current study suggest that a reduction in touch pleasantness is not a consequence of a symptom of anorexia such as starvation, but a trait present even post recovery.

Contradictory to the predictions, no group differences were observed for third party ratings of pleasantness of touch for another. Given than people with AN have found to have an impaired ToM, even post recovery (de Sampaio et al., 2013; Gál et al., 2011; Hamatani et al., 2016; Konstantopoulos et al., 2020; Russell et al., 2009; Tchanturia et al., 2018; Zucker et al., 2007), it was anticipated that both women with AN and RAN would use their own (possibly negative) experiences of touch to predict the experiences of touch for another. Instead, the findings from study 2 offer support for the lack of differences in cognitive perspective taking between women with AN and HCs (Adenzato et al., 2012; Bora & Köse, 2016; Calvo et al., 2014; Medina-Pradas et al., 2012). This could be consequent to learned experiences of observed touch guiding their interpretation of touch for another, regardless of whether they themselves find touch unpleasant (Korkmaz, 2011). As outlined by Tagini et al. (2023), the experience of affective touch in people with AN may be explicitly related to their expectations of pleasure and this is limited to their own experience of touch, as opposed to the pleasantness of touch itself. As outlined in study 2 (Chapter 4), individuals with AN may have learned that affective touch can be pleasantly experienced by others, but they are aware that this pleasantness of affective touch is not experienced by them (Bellard et al., 2022; Tagini et al., 2023). Therefore, as specified by Tagini et al. (2023), if such relationship exists in people with AN between social anhedonia (lack of pleasure in social situations) and the experience of affective touch, this could be more explicitly related to what individuals with AN expect to be pleasant (anticipatory) than consummatory pleasure (the enjoyment of a present experience) of affective touch (Tagini et al., 2023). Therefore, future studies should investigate how learned experiences may play a role in the distinction between touch wanting and touch liking and how anticipatory expectations influences touch experiences in individuals with AN.

In addition, we also wanted to understand whether specific facets of body awareness and intimate touch experiences, may be associated with vicarious social touch responses, when touch is self-directed compared to other-directed, in both clinical populations. We specifically focused on trusting as our body awareness predictor, given that Brown et al. (2017) reported there is a strong relationship between this and eating disorder psychopathology. However, this was not the case in study 2, as this factor did not predict ratings of vicarious social touch in women with AN or RAN. Thus, it could be that other factors of interoception may be predicting these responses, such as interoceptive sensibility scores, found in the study of Crucianelli et al. (2021). This is a particularly important factor which should be considered in the future, when assessing vicarious responses to social touch in women with AN and RAN. With regards to intimate touch as a predictor for responses to self-directed touch in both clinical populations, this was only observed for women with AN and HCs. It was revealed that positive attitudes to intimate touch was positively associated with overall touch pleasantness regardless of velocity for women with AN, for self-directed touch. This finding supports the implication that people with AN may tend to struggle and find closeness discomforting and have difficulty in maintaining close intimate relationships with a romantic partner, family, and friends which could be accounted for by their dislike towards touch and intimacy (Evans & Wertheim, 1998; Zucker et al., 2013).

7.3.3 Vicarious self-directed social touch responses from a loved one and an acquaintance

Another aim of this PhD project was to assess the imagined perception of soothing and unpleasantness responses to self-directed social touch in real life affective scenarios i.e., whether social context facilitates pleasantness responses, in individuals with high and low levels of BIDs. Furthermore, it was anticipated that for the high levels of BIDs group, greater levels of unpleasantness to touch, regardless of whether this is from a loved one or an acquaintance, was associated with higher levels of dysmorphic concerns and greater interoceptive deficits. This was the first study to assess these aims using a virtual mobile phone application, specifically the 'Virtual Touch Application'. As specified in Chapter 1, individuals with AN demonstrate negative responses to touch, even if this touch has been provided from a familiar person i.e., loved one such as a romantic partner (Arcelus et al., 2012).

Overall, as anticipated, evaluation of social touch was relationship specific, with touch delivered from a loved one being evaluated as more soothing/pleasant compared to when this touch was provided from an acquaintance. As outlined by Suvilehto et al. (2015, 2019), this is due to the fact that touch provided from a loved one is more familiar and given more frequently than touch from an acquaintance (Jones & Yarbrough, 1985; Nummenmaa et al., 2016; Strauss et al., 2020; Suvilehto et al., 2015, 2019). As a result, touch from a loved one will be rated as more pleasant than touch from an acquaintance. The regions that an acquaintance is able to touch is restricted to the hands and upper torso only (Suvilehto et al., 2015, 2019).

Moreover, it was anticipated that the high levels of BIDs group would demonstrate greater levels of unpleasantness to touch, regardless of the touch provider. In the current study, this was not the case, as in Cash et al. (2004), the high levels of BIDs group did not demonstrate comparable responses to individuals with AN, as they did not evaluate touch from a loved one as unpleasant. Instead, we did not observe any differences between high and low levels of BIDs in their evaluation of touch. These results are in line with what was found also in study 1 (Chapter 3), in which no differences were observed between high and low EDs risk relating to pleasantness of touch responses. Therefore, it could be argued that atypical affective touch responses are a consequent of starvation associated with AN and does not manifest until after an individual has AN as opposed to before

(Gołębiowska et al., 2022). The findings from study 3 (Chapter 5) offer further support for the findings from Bischoff-Grethe et al. (2018), who found that individuals with RAN displayed similar affective touch responses to HCs.

When looking at individual body parts, touch to the hands and upper arms were the only regions rated as pleasant from an acquaintance for the high levels of BIDs group and for the low levels of BIDs group this was only for the hands. This was unexpected given that it was anticipated that all body parts would be evaluated as unpleasant for high levels of BIDs, regardless of this touch being provided by a loved one or an acquaintance. Nonetheless, this finding was in line with more recent research conducted by Tagini et al. (2023) who did not observe any differences in pleasantness ratings of social touch in people with AN and HCs. Also, this finding supported what was found previously by Suvilehto et al. (2015, 2019). The findings from study 3, did not support the results from study 2, in which women with AN demonstrated clear differences in responses to vicarious touch for the self, demonstrating more unpleasantness to touch compared to HCs. A possible explanation for such findings from study 3, could be that both groups of women were more representative of the general healthy population detailed in Suvilehto et al. (2015, 2019), as opposed to the high levels of BIDs group behaving more comparable to individuals with AN would. Thus, it would be of interest to investigate responses to social touch delivered from various relationships, to see whether individuals with AN and recovered from AN also display relationship specific responses to social touch, similar to the high levels of BIDs individuals did in study 3.

Furthermore, although we did not observe any clear differences between groups, comparable to low levels of BIDs, high levels of BIDs individuals evaluated intimate regions as unpleasant and social regions as soothing. Intimate regions in study 3, comprised of body areas such as the abdomen and thighs. Given that these regions are of concern in eating disorder patients due to being weight-sensitive (Ralph-Nearman et al. 2019, Irvine et al. 2019), it was expected that touch to these regions would be evaluated as more unpleasant as opposed to soothing in individuals with high levels of BIDs. A possible explanation as to why low levels of BIDs individuals also rated these regions as unpleasant could be due to the fact that body image concerns still manifest in the general population and these are regions women find to be unattractive, as they are areas more susceptible to weight gain (Bauer et al., 2017; Bellard et al., 2020; Ralph-Nearman et al., 2019; Horndasch et al., 2012).

Lastly, we also wanted to understand whether responses to social touch for high levels of BIDs was associated with higher levels of dysmorphic concerns and greater interoceptive deficits. The results from study 3 (Chapter 5) demonstrated for the high levels of BIDs group, an association with emotional awareness and ratings for touch to intimate and social regions from a loved one and an acquaintance. Specifically, greater levels of emotional awareness, was associated with higher soothing ratings for touch. This finding provides an important addition to the current literature on touch, demonstrating an involvement of emotional awareness in response to touch in individuals with high levels of BIDs.

7.3.4 The neural basis of vicarious ratings of social touch

As outlined in Chapter 1, affective touch is a process which involves a plethora of brain regions alongside the Insula Cortex, some of these regions are key in social cognition. Previous research has demonstrated the involvement of the mPFC, a region involved in the coding of social reward of tactile stimuli (Gordon et al., 2013). Also, there has been studies which have shown an association with the visual processing of pleasant affective touch and S1 activation (McCabe et al., 2008; Gazzola et al., 2012). Based on these previous studies, in Study 4 (Chapter 6), we aimed to establish whether inhibitory Transcranial Magnetic Stimulation (rTMS) over the right S1 and vmPFC is causative of atypical vicarious affective touch responses respectively in self and other-directed touch, in relation to ED symptomatology.

Overall, the results from this investigation highlighted the distinctive role of S1 in self-directed touch and the vmPFC in other-directed touch. Also the important role of S1 in targeting self-directed touch therapies. Specifically, we expected that S1 inhibition would result in a reduction in the pleasantness ratings for self-directed touch. However, this was not the case in study 4, as instead, inhibition of S1 resulted in greater wanting ratings for self-directed touch, indicating involvement of S1 in the visual processing of self-directed touch. In particular, our results offer support towards the idea that S1 is involved in the visuo-tactile mirroring of self-directed touch when observing another person receiving touch (Blakemore et al., 2005; Keysers et al., 2004). When we view another person receiving touch, S1 generates a shared tactile representation of the hedonic sensations as though we are also directly experiencing the touch being perceived (Adler et al., 2016; Blakemore et al., 2005; Bufalari et al., 2007, Deschrijver et al., 2016; Ebisch et al., 2008, Keysers et al., 2004, Pihko et al., 2010, Schaefer et al., 2009, Wood et al., 2010). Nonetheless, if this was the case, it would be expected that inhibition of S1 would result in a decrease in wanting to be touched based due to the inability to experience the same somatic feelings generated by the positive touch being observed. Instead, a possible explanation, as outlined in Chapter 6, in line with the predictive coding framework (Huang & Rao, 2011; Millidge et al., 2022), might be that we added additional noise into the signal for S1 when inhibiting this region. The brain is classified as a predictive machine and uses the incoming signals to constantly update a mental model of an action (Beal, 2003) i.e., the observed touch. Due to the addition of noise into this incoming signal, this may have led to greater errors in prediction in pleasantness for touch for another, these errors would have been classified as unreliable. As a result, the brain may have used past experience of observing touch for another in these evaluations of touch, causing participants to rate this touch as pleasant regardless of S1 inhibition. As suggested by Case et al. (2016), it could be that S1 may be involved in the coding of intensity of touch as opposed to the pleasantness of touch (Case et al., 2016).

With reference to vmPFC, given that this region is largely involved in social cognition, specifically in theory of mind and inferring other people's intentions, mental states and attributing emotional states to others (Mar, 2011; Schurz et al., 2014; Sperduti et al., 2011), as anticipated, inhibition of the vmPFC resulted in the reduction in pleasantness ratings when making inferences about pleasantness of touch for another person. This is due to the fact that disruption to this region, would result in greater number of predictive errors in inferring the emotional state of another. Therefore, participants would be unable to infer how pleasant they think another individual would find that touch to be (Stuss et al., 2001). Overall, this finding suggests causative evidence for the dysfunction of the vmPFC and atypical responses to affective touch in individuals with AN when making inferences for another person (Koechlin, 2011), which could be connected with the social impairments in AN (de Sampaio et al., 2013; Schmidt et al., 1995; Godart et al., 2004; Russell et al., 2009). Nevertheless, this finding was not CT-specific, meaning that other regions are supposedly involved in the central processing of CT-optimal touch when touch is given to another person.

Moreover, inhibition to the vmPFC did not result in a reduction in pleasantness for self-directed touch. The vmPFC is a region involved in the attribution of mental states associated with the self (Frith & Frith, 1999; Schurz et al., 2014). As disruption to this region did not have any influence on self-directed pleasantness responses for social touch, a possible explanation could be that other regions of the prefrontal cortex such as the ventro-medial region, may support self-attribution (Northoff et al., 2006; Northoff & Bermpohl, 2004).

Furthermore, this investigation aimed to examine the links with pleasantness ratings of affective touch and eating disorder traits, such as interoceptive deficits and body image concerns (Crucianelli et al., 2016; Davidovic et al., 2018; Kaye, Fudge, & Paulus, 2009; Pollatos et al., 2008) and body image misperception (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016; Perez, Coley, Crandall, Di Lorenzo, & Bravender, 2013). Moreover, pleasantness ratings for cTBS S1 for other-directed touch revealed that the higher the willingness to be touched, regardless of CT-optimal touch, the higher the levels of emotional awareness (Adolphs et al., 2000). Thus, participants with higher levels of emotional awareness rate they would like to receive touch more, following inhibitory stimulation of the S1, than following vertex stimulation. A possible explanation could be that given that the right somatosensory cortex plays a role in visual emotion recognition (Adolphs et al., 2000), one would expect that as pleasantness ratings increase, so would awareness of emotions. Emotional awareness is important in recognising self and other individuals emotions. As such, emotional awareness necessary for human psychosomatic health and homeostatic processing, disturbance in this type of awareness leads to the inability to recognise emotions both for self and another person (Kanbara & Fukunaga, 2016). With regards to self-directed touch in the current study, emotional awareness would be particularly important in recognising the positive evaluation of affective touch directed to the self and this would lead to greater pleasantness ratings. Given that inhibition of S1 increased pleasantness of touch for the self, one would expect that this would correlate with increased emotional awareness. Thus, the higher the emotional awareness, the greater the recognition that touch directed to the self to be more pleasant.

7.4 Methodological Limitations

7.4.1 Research participants

Throughout all studies except for study 3, the samples selected in all 3 experiments consisted of female participants only. Also, it is important to note that the sample of males recruited in study 3 consisted only of 22 males compared to 47 females (See appendix 11, for an additional analysis demonstrating the lack of differences between both Genders; Bellard et al., 2023). A main consideration for the focus on female participants throughout this thesis, was that eating disorder symptomatology manifests differently in males compared to females (Stanford & Lemberg, 2012). Also, the prevalence rate of eating disorders is more common in females compared to males (APA, 2013). However, less is known currently regarding eating disorders in males and as such, the interest in this population is growing and is developing (Murray et al., 2017), hence, the inclusion of this population in study 3 investigation. The inclusion of this population in study 3, opens up the opportunity to delve more into the link with eating disorders in males and responses to social touch. Recruiting women in the current thesis was advantageous as it enabled for the comparison between previous literature and findings in the current investigations. Also, as this investigation was focused on touch responses, it was important to use females, as there are differences in responses to touch in females and males (Russo et al., 2020).

Furthermore, in studies 1, 3 and 4, all participants were of the general "healthy" population, who self-reported varying levels of subclinical eating disorder symptoms. Although this was beneficial, as you could control for confounding variables present in clinical populations such as abnormal body mass index causing cognitive and perceptual impairments, medication effects and starvation impacts to functioning, it is important in the future to investigate whether the results in the current thesis could be generalised to eating disorder populations. Although study 2 provides findings for vicarious social touch responses in women with AN and recovered AN, it would be useful in the future to use these populations when assessing social touch responses when provided by different relationships.

Moreover, it is evident in the samples, particularly for study 1, that those participants reporting a higher risk for an eating disorder, also had higher reported BMI scores. Although this can be perceived as unusual for these populations, this finding is also in line with Killen et al. (1996) who demonstrated that a higher BMI is predictive of a future onset of an eating disorder. However, the association between BMI and EDs has received many criticisms, with other studies failing to replicate this finding (Patton et al., 1999; Stice et al., 2017). Therefore, the association with BMI scores and onset of an eating disorder should be further explored, as this information will be particularly useful when investigating risk of an eating disorder.

In addition, as outlined in study 2, using a self-report diagnosis may pose some issues, particularly with the variability of individuals in these clinical populations. As a result of this, the full scale of different forms and severity of AN (APA, 2013) are not accounted for. Furthermore, those who self-reported having recovered from anorexia may be at risk of or are undergoing relapse, given that this disorder has one of the highest cases of relapse rates (Khalsa et al., 2017). Moreover, not only does this raise concerns with the eating disorder populations, but also with the healthy populations, as some individuals in this population may have an undiagnosed eating disorder or may be individuals with an eating disorder who may not with to disclose that they have one. Based on all these scenarios, there was a strict BMI classification put in place for diagnostic criteria purposes. This ensured that all participants recruited were classified into the correct groups (AN, RAN and HCs) and those who did not, were excluded from the data analysis. Those with a BMI below 18.5kg/m^2 was used as the cut off for the AN group and for both the RAN and HCs, all participants had to have a BMI over 18.5kg/m^2. This was particularly important for the RAN groups, to be certain participants were not relapsing.

BMI above 18.5kg/m^2 is indicative of a healthy BMI range. Also, the EDE-Q (Fairburn & Beglin, 1994) was used as another measure of eating disorder risk. As outlined by Wolk et al. (2015), the EDE-Q (Fairburn & Beglin, 1994) is a reliable measure to utilise as an alternative assessment to examine AN diagnosis, in substitute of the eating disorder examination interview (Fairburn, Cooper, & O'Connor, 1993, 2008). Nevertheless, using self-reported eating disorder diagnosis for study 2, may not have posed any concern for the sample, as given that this study was conducted virtually, patients are more probable in being honest and open about their eating disorder diagnosis, compared to if the study was carried out face-to-face, as there is more anonymity in an online investigation. As well as this, participants were provided with screening questionnaires prior to study completion. These questions ensured that those individuals who did not meet the criteria for an eating disorder, recovered from an eating disorder or a healthy control, could not take part in the study. These individuals were automatically displayed with the debriefing document. In addition, due to the Covid-19 pandemic, it was problematic for communicative reasons and limited resources to get in contact with charities, in order to have a direct connection with patients to conduct the clinical interviews. Nonetheless, it will be beneficial in the future to conduct clinical interviews as an assessment for AN diagnosis, in order to obtain a certified diagnosis from a qualified clinician (Sysko et al., 2015).

7.4.2 Affective Touch Videos

The affective touch videos were selected for studies 1 (Chapter 3), 2 (Chapter 4) and 4 (Chapter 6) in order to measure vicarious social touch responses in clinical and non-clinical populations. Although these videos are an alternative way to assess social touch responses without having to provide real touch which could be distressing to clinical populations, as these populations experience greater intensity and hypersensitivity to real touch (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016, 2021), there are some important methodological limitations to consider for future research. Firstly, the videos do not fully reflect first person view of someone observing another individual receiving touch. A first-person view of observing another receiving touch would enhance participants embodiment of the touch they are perceiving, as this viewpoint would reflect lifelike observations (Kessler & Thomson, 2010). Therefore based on this assumption, it would be beneficial for future research to assess vicarious ratings to social touch using first person perspective videos as opposed to third-person perspective videos used in the current study. It would be beneficial to incorporate eye-tracking techniques in order to assess where clinical and non-clinical populations focus when observing touch i.e., due to these populations demonstrating avoidance to touch (Zucker et al., 2013), whether they also avoid observing another individual observing touch. Alternatively, another possible way to achieve first person perspective observation of social touch would be through Virtual Reality systems. Although virtual reality is artificial, this type of system creates a virtual realistic world in which participants are fully immersed without any distractions. The participant can be subject to a virtual setting in which they are perceiving someone else receiving touch, or they themselves are virtually receiving touch to different body regions. This type of virtual world has been previously created (Seinfeld et al., 2022) and has shown to be more beneficial than using laboratory-based measures such as videos, as virtual reality is able to incorporate the intimate side of social touch which is not generated viewing video clips (Fusaro et al., 2021).

Moreover, it is important to consider various social and contextual factors which may influence social touch responses (Sailer & Leknes, 2022). Given that previous research (Suvilehto et al., 2015, 2019) and study 3 has demonstrated that touch responses in largely influence by relationship, it would be beneficial in the future when showing participants social touch videos, to ask them to imagine the touch from their partner. This touch has found to be most rewarding compared to receiving touch from other individuals such as a stranger. Also, partners are accepted to touch more areas of the body (Suvilehto et al., 2015, 2019). Therefore, by asking participants to imagine this type of touch from a partner, there is more control over the person they are imagining receiving the observed touch from. It was not certain whether participants in the current PhD project were imagining the touch being provided from the actor they was observing (stranger) or if they was imagining the touch in a real-life setting (from a loved one).

Furthermore, in relation to the use of male as the touch provider and female as the touch receiver was selected given that compared to females, males instigate touch more frequently (Henley, 1973; Stier & Hall, 1984). Also, all participants observing the affective touch videos in the current PhD Thesis were all female. However, in order to ensure participants fully embodied the touch they was observing, it would be important in the future to ask participant's sexual orientation to ensure that the sex of the touch provided i.e., their partner, represents the touch they receive in their real life. Also, it would be important to ask for participants relationship status and satisfaction in their relationship, as those who receive more experiences of positive touch from a partner may have more positive responses to touch compared to those who are single and do not receive touch from a partner (Triscoli et al., 2017).

A final point to consider is the wording for the questions used for both self-directed and other-directed touch, which may add a potential confound to the interpretation of data. These questions were used in order to measure how experiences of vicarious touch might influence responses to the observation of social touch (Haggarty et al., 2013). For self-directed touch the question included: "How much would you like to be touched like that?". This question reflected more of an explicit evaluation of CT-specific touch, specifically relating to the wanting of the touch the participant was observing. For other-directed touch, the question asked participants to respond to: "How pleasant do you think that action was for the person being touched?". This question measure an implicit evaluation of the pleasantness of touch the female who is receiving the touch. It may also be important in the future to change the wording in relation to the self-directed touch question in order to reflect a more pleasantness response as opposed to wanting. This would allow for comparisons to be made between both questions as they would examine similar responses.

7.4.3 Transcranial Magnetic Stimulation (TMS)

The neurophysiological technique used in this thesis was TMS, a measure which was incorporated to understand the neural underpinnings of vicarious affective touch. As outlined in study 4 (Chapter 6), this technique is a safe, non-invasive brain stimulation technique which enables the investigation of the causative role of a brain region to a specific function, without any serious side effects or stimulation having long-lasting effects (Chail et al., 2018). This measure allows for researchers to temporarily inhibit the function of a specific region to assess the impact on a behaviour to establish the causative relationship (Hallet, 2007). Over the years, the improvement and development in the shape of the coil has enabled researchers and therapists to gain more control over the region they are targeting, without causing disruption to nearby regions (Chail et al., 2018). Participants experience no discomfort and although they are aware of the disruption to the function of the target brain region, they do not get any sensations from this.

Similar to many experimental techniques, TMS has its limitations for use in research purposes. A main limitation to this protocol is the important safety procedures needed to be adhered to in order to reduce the risks to participants (Horvarth et al., 2011; Rossi et al., 2021). The use of the extensive list of inclusion and exclusion criteria can result in many potential participants being excluded for their own safety, making it more difficult to recruit participants (Rossi et al., 2021). In addition to reducing the number of subjects, the safety procedures adhered to result in changes to behavioural protocols in order to comply with the safety guidelines. This generally has implications for the design of the study, such as the length the experiment is able to be, the number of trials and the need for 48 hours between sessions for certain TMS stimulation protocols (Rossi et al., 2009, 2021). For the current investigation, this did not impede the overall design. The requirement for 3 sessions and 48 hrs in between, resulted in small effects in the participant numbers, with only 1 individual dropping out of the study. In addition, the stimulation sites which can be targeted are limited with TMS due to stimulation depth being 2 - 3 cm and the magnetic field reducing in intensity further away from the coil (Najib et al., 2011; Roth et al., 1991; Zangen et al., 2005). With regards to the stimulation sites used in the current study, establishing a causative role with more subcortical regions such as the Insula Cortex could not be achieved. However, the changes in focusing on vicarious responses to social touch as opposed to responses to actual touch, resulted in regions such as the mPFC and S1 being more appropriate to target (Blakemore et al., 2005; Keysers et al., 2004). Nonetheless, advancements in TMS equipment such as the H-Coil and Transcranial ultrasound are making reaching regions such as the Insula Cortex more plausible (D'Argembeau et al., 2007; Samoudi et al., 2018; Sperduti et al., 2011; Zangen et al., 2005).

Another limitation of TMS is that stimulation can cause auditory and somatosensory side effects, which is due to the changing magnetic field. Each magnetic pulse produces noise such as clicking, which is louder if the region is closer to the ear and tapping sensations producing muscular contractions, which are evident in more ventral regions (Mennemeier et al., 2009). The sensations and noise produced by the coil may interfere with a subject's performance and responses on a task (Duecker & Sack, 2015). For the current study, auditory and somatosensory side effects did not impede with the behavioural responses to the task, as all stimulation was provided prior to any task and only lasted a small duration of 40 seconds.

A final limitation, which should be controlled for in future studies is the combination of fMRI with TMS. It has been previously proposed that without the combination of techniques such as fMRI, there is no way to be certain that TMS was having any impact on surrounding brain regions and that the target region was significantly inhibited compared to pre-TMS stimulation (Bestmann et al., 2008). In using TMS and fMRI in the same investigation, it is possible to examine brain functioning of the targeted region before and after TMS, to be certain that stimulation has significantly inhibited this region and that the effects have not caused any inhibition to surrounding regions. This will ascertain a causative role between the inhibited region and the behaviour (Bestmann et al., 2008).

7.4.4 Neuronavigation

The use of a Neuronavigation method, used in study 4 (Chapter 6), is a more precise method for the localisation of TMS to a specific region, compared to other standard practices such as using an EEG cap (Chail et al., 2018). This system ensures that during the stimulation phase of experimentation, the TMS coil remains localised on the region of interest (Julkunen et al., 2009; Krings et al., 2014; Ruohonen & Karhu, 2010). Although this method for TMS localisation has its benefits, using this method in combination with actual MRI scans makes the navigation more precise, as every individual is different (Ruohonen & Karhu, 2010). In the future, it would be beneficial to collect and use participants' individual scans, to ensure that each localisation is tailored to each individual (Ruohonen & Karhu, 2010).

7.4.5 The impacts of Covid-19

During 2020, the UK was subject to a global lockdown due to a virus, referred to as Covid-19. In order to contain the spread of the virus, a number of public health methods were implemented globally. One of the main measures used was to limit physical and social interactions through social distancing and quarantine. One main component of social interactions which was affected by this measure was the ability to engage in direct social touch (Verity et al., 2020). This was particularly in place for social interactions with individuals outside of your household (Meijer et al., 2022). Due to these restrictive measures being in place, the current study focused on vicarious ratings to social touch, as opposed to actual touch. The impacts of Covid-19 on responses to vicarious touch was measured, particularly in studies 1 and 2 (Chapters 3 and 4) given that these were collected during the global lockdown, and 3 and 4 (Chapters 5 and 6) which were collected when social distancing measures were in place. Although it was expected that individuals' responses to touch would be atypical due to touch deprivation, resulting in more longing for or avoidance of touch (von Mohr et al., 2021), Covid-19 did not have any influence on overall touch pleasantness for any groups in either study 1 (Chapter 3) and 2 (Chapter 4).

Nevertheless, this PhD thesis provides new and important findings regarding responses to vicarious social touch in individuals with AN, given their difficulties in social skills (Courty et al., 2013). Therefore, in the future, it would be beneficial to have a real touch condition in addition to imagined self-directed touch, as in Crucianelli et al. (2021). This would allow for a comparison to understand whether these populations have atypical responses to both actual and imagined touch. Nevertheless, it is important to note that this was not possible at the time of data collection, due to lockdown consequent to the Covid-19 pandemic.

7.5 Future Directions

As outlined in Chapter 1, due to the complexity of AN, previously established interventions such as family-based therapy, cognitive behavioural therapy, group cognitive based therapy, medication and hospitalisation have been unsuccessful and patients have disengaged (Costanzo et al., 2018). As a result of the lack of effectiveness of these treatments, in the UK alone, treatment is costing the economy £18 billion, due to the frequent relapse rates of patients. Also, this disorder has the highest reported fatality rates of any mental health condition (Costanzo et al., 2018). Based on this, the UK National Institute for Health and Care Excellence have underlined the necessity for novel treatment interventions for AN such as TMS (Habib et al., 2018). TMS has the capacity to help improve inter-neuronal connectivity which have been impaired in individuals with AN and enhance brain functioning (Duriez et al., 2020; Luan et al., 2014).

7.5.1 A future novel TMS-based intervention for self-directed social touch in AN

Based on the requirements for more novel treatment interventions for AN to be developed, this PhD thesis has opened up the opportunity to pilot and develop a future non-invasive brain stimulation aimed at targeting atypical responses to self-directed affective touch in individuals with AN. In particular, this PhD project has provided more information specifically that atypical responses to vicarious social touch in individuals with AN and RAN occurs explicitly for self-directed touch as opposed to other-directed touch (Study 2). This study has also provided evidence that these atypical responses still manifest post-recovery from AN. Study 4 (Chapter 6) has provided an understanding that vicarious responses to social touch for self is mediated by the processing of S1, but has also opened up the opportunity for further research to explore other brain regions which may be involved in the processing of affective touch in AN, such as the orbitofrontal cortex (OFC) (Rolls, 2004) and anterior cingulate cortex (ACC) (Lindgren et al., 2012). Once the key regions are established, which are causative of atypical responses to affective touch in AN, a pilot study can be adopted which incorporates TMS as an intervention, with the aim of improving the functioning of these regions. This could be achieved through administering approximately 20-30 sessions of neuro-navigated high frequency repetitive TMS to regions involved in atypical social touch responses. In order to assess the effects of this intervention, important information concerning participants BMI, eating disorder risk, interoceptive awareness, touch experiences and attitudes towards receiving touch will be measured pre- and post-treatment and also at 6 months and 12 months follow up after intervention completion. If shown to be successful, this pilot can be tested on a larger scale and has the potential to revolutionise treatments and reduce relapse and mortality rates.

In addition, if as shown in study 4 (chapter 5) S1-cTBS improves willingness to receive self-directed touch, then targeting this region could be useful in improving overall self-directed touch processing in patients regardless of the CT-optimality. This future non-pharmacological intervention could be given to both individuals with AN and RAN, given that study 2 (Chapter 4) demonstrated that atypical responses to affective touch still manifests post-recovery from AN. The same protocol (theta-burst stimulation) described in study 4 (chapter 6) could be utilised across various sessions, given that wanting for touch increased post stimulation to S1. Also, this intervention could be used as an alternative to targeting the Insula Cortex, given the complexity to stimulate this region (Knyahnytska et al., 2019; Lee et al., 2020).

7.5.2 A future novel virtual touch application for self-directed social touch in AN

In addition to brain stimulation interventions, the virtual touch app (Study 3, Chapter 5) can also be used as a potential novel treatment for individuals with AN. Incorporating self-touch as a treatment intervention could help with reducing the stress and discomfort associated with touch in individuals with AN (Dreisoerner et al., 2021; Neff & Germer, 2013). In particular, this application can be used to help with interpersonal difficulties associated with AN, in particular from loved ones and also in clinics, through the imagination of touch, without the stress and discomfort associated with receiving actual touch. This would help build positive relationships between patients and clinicians and can help with bettering experiences and success of these treatments

(Kelly et al., 2018), particularly if these treatments involve touch (Vandereycken et al., 1987). In addition to the established positive outcomes associated with body-orientated therapy and massage therapy for patients with eating disorders (Field et al., 1998; Hart et al., 2001), research has also revealed that touch positively facilitates the interactions between health professionals and their patients (Kelly et al., 2018). Specifically, touch between these two individuals helps build boundaries, expresses caring and encourages emotional closeness, which is important in body-orientated therapies in AN. These therapies require physical contact between health professionals and patients as part of the therapy. The 'Virtual Touch Toolkit' can serve as a virtual space, resembling real life scenarios in which patients can engage in self-touch behaviours and also focus on interpersonal interactions, specifically interpersonal touch with different individuals such as strangers or health professionals without the requirement of direct physical contact. Therefore, in the future, the practicality of this application in imagined social touch for rehabilitative purposes in body-orientated therapy in AN should be investigated.

7.5.3 The benefits of self-directed touch interventions for AN

As demonstrated in study 2 (Chapter 4), women with AN and RAN rated CT-optimal self-directed vicarious social touch as significantly less pleasant than healthy controls. This finding did not extend for judgements for pleasantness of touch for another person (other-directed touch). Therefore, given that this study (Chapter 4) demonstrates that atypical responses to social touch in AN occurs only for self-directed touch, it is important for interventions to focus on this type of touch. Self-directed social touch is suggested to be important for self-body representation (Gentsch et al., 2016; Ciaunica & Fotopoulou, 2017), as this type of touch is believed to be a sub-modality of interoception, processed by the Insula Cortex (Krahé et al., 2018). Social touch has been found to enhance bodily ownership in individuals with clinical populations (Jenkinson et al., 2019). Different components of interoception has different impacts on bodily awareness (Crucianelli et al., 2018). Therefore, self-directed touch therapy will help overcome impairments in interoception and help with the development of bodily ownership and self-body awareness and representation.

As well as physiological representations of the body, self-directed touch could help with improving the visual and mental representation of the body in patients with AN, as touch is important in understanding and perceiving our body in the environment (Spitoni et al., 2010). This is particularly important in this population given that they tend to have overestimations and dissatisfaction in their body image, which leads to symptoms associated with AN such as abnormal eating behaviours in order to lose weight (Farrell et al., 2005; Smeets et al., 1997; Skrzypek et al., 2001; Stice & Shaw, 2002).

Furthermore, self-directed touch interventions could have the ability to enhance social impairments between AN and key relationships in their life such as loved ones and clinicians, making treatment more bearable for these populations. Social touch is an important component in bonding and communication with others (Brauer et al., 2016; Cascio et al., 2019; Morrison et al., 2010; von Mohr et al., 2017). This type of intervention can help improve atypical interpersonal and social cognitive functions, which could be linked to the onset and maintenance of AN (Arcelus et al., 2013; Castro et al., 2010; Zucker et al., 2007).

7.6 Conclusions

Overall, one of the main aims of this PhD project was to investigate whether individuals with anorexia display atypical self and other-directed vicarious social touch responses. Also to understand the neural underpinnings potentially surrounding the evaluations of self and other-directed social touch in AN. The penultimate goal of this PhD was to inform current knowledge of non-pharmacological treatments of EDs which might incorporate TMS as a novel non-invasive brain intervention. This intervention could utilise TMS to focus on the regions mediating atypical pleasantness responses to self-directed affective touch in EDs.

Taken together, the results suggest that women with AN and recovered from AN, display comparable intact evaluations when comparing touch for another person, comparable to that of HCs. Atypical vicarious touch responses occur when both individuals with AN and RAN are asked to make judgements for touch to the self. Both groups rated self-directed affective touch as less pleasant for the self, compared to healthy controls. With regards to women at risk of an ED, no differences occurred between high and low EDs risk. However, women recruited in these populations could be more representative of neuro-typical individuals as opposed to subclinical groups and the need to understand atypical responses in clinical groups was required. The results from the subclinical groups suggest that responses to affective touch are intact even if women display heightened risk of an eating disorder. Thus, as demonstrated in both clinical groups in study 2, these atypical responses to social touch for the self must manifest both when AN is present and remains even when recovered from AN and not prior to the onset of this disorder.

With reference to the neural underpinnings of vicarious social touch, findings revealed that the vmPFC is involved in the observation of someone else receiving touch. This could occur because of participants being more able to embody the experience of touch and making inferences about the rewarding value of the touch for others. Inhibition of this region revealed that participants may fail to make inferences about others' intentions and mental states i.e., as their ability to attribute emotional states to others decreased compared to cTBS delivered over S1 and vertex. As a result of this inhibition, participants evaluated touch for another as less pleasant. Furthermore, that S1 resulted in an increased evaluation of self-directed vicarious touch and more wanting to receive touch. This was not CT-optimal specific, implying that CT-optimal touch is encoded in other regions and not in the vmPFC and S1. Based on this, future studies would be useful to investigate other regions which may be involved in atypical affective touch processing in AN such as the orbitofrontal cortex (OFC) (Rolls, 2004) and anterior cingulate cortex (ACC) (Lindgren et al., 2012), particularly focusing on self-directed touch as opposed to other-directed touch.

Finally, given that clinical groups displayed atypical social touch responses for self-directed touch, we wanted to delve further into whether touch is relationship dependent, in individuals with high and low body image disturbances. Using a novel mobile application, it was revealed that soothing responses to social touch was largely dependent on the relationship shared with the touch provider. Touch was evaluated as more soothing when provided from a loved one and unpleasant when given by an acquaintance. Furthermore, this application can be used in the future to assess vicarious social touch responses in people with AN in different settings, such as when touch is provided from a clinician compared to various social relationships such as family, partner, or friends.

Overall, all findings offer valuable insight into responses to vicarious social touch in women at risk of an EDs, women with AN and recovered from AN and provide for the potential for future pilot studies to be developed, incorporating both TMS and mobile applications as an intervention for AN. Given the potential positive use of the Virtual Touch Toolkit with individuals with high BIDs risk, future research could pilot this application as an intervention for atypical responses to touch in clinical populations such as AN and can use this application as a potential self-touch therapy, which could have positive, soothing effects on reducing stress responses such as cortisol levels (Dreisoerner et al., 2021; Neff & Germer, 2013). This tool also has the benefits to be used to target interpersonal difficulties which manifest in AN. In addition, given the extensive, beneficial use of TMS in treatment for conditions such as depression (Loo & Mitchell, 2005) and also in AN (McClelland et al., 2016), in the future, this technique can be piloted as a potential novel non-invasive intervention, for the targeting of those brain regions impaired in response to social touch responses in individuals with AN, which could focus on S1 given that touch wanting increased following cTBS-S1.

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Appendices

Appendix 1: Screening Questionnaires

Studies 1, 2 and 4

You do not have to answer any questions you do not feel comfortable with. We kindly ask you to send it back within one week.

a. **I confirm that I am 18 years or over.**

TRUE FALSE

b. **I confirm that I am Female.**

TRUE FALSE

b. **I confirm that I have not got a current or previous diagnosis of an Eating Disorder.**

TRUE FALSE

c. **I confirm that I do not suffer from any form of skin condition (i.e., Eczema/ Psoriasis).**

TRUE FALSE

d. **I confirm that I do not suffer from any Chronic pain condition (i.e., Fibromyalgia/ Arthritis).**

TRUE FALSE

e. **I confirm that I am not pregnant.**

TRUE FALSE

f. **I have normal or corrected vision (i.e., glasses/contact lenses).**

TRUE FALSE

g. **I have read the information sheet provided and I agree to take part to this study.**

I AGREE I DISAGREE

Appendix 2: Demographic Questionnaires

Studies 1 and 2 (including screening questions for AN diagnosis)

1. **Please specify your Sex:**

   Male ☐

   Female ☐

   Other ☐ (Please specify) ________________

   Prefer not to say ☐

2. **Please specify your Age:**

   ____

3. **Please Specify your ethnicity:**
   White British ☐
   White Irish ☐
   Black Caribbean ☐
   Black African ☐
   Indian ☐
   Pakistani ☐
   Bangladeshi ☐
   White and Black Caribbean ☐
   White and Black African ☐
   White and Asian ☐
   Chinese ☐
   Japanese ☐
   Other ethnic background ☐ (Please specify) _________________

4. **Please specify your current diagnosis of Anorexia Nervosa:**
   Current diagnosis of Anorexia Nervosa ☐
   Previous diagnosis of Anorexia Nervosa ☐
   No Diagnosis/history of Anorexia Nervosa ☐

5. **If you have a current diagnosis of Anorexia Nervosa, for how many years have you had this? (If you do not have a current diagnosis of Anorexia Nervosa, please skip).**

____

6. **If you have a previous diagnosis of Anorexia Nervosa, for how many years have you been recovered? (If you do not have a previous diagnosis of Anorexia Nervosa, please skip).**

____

7. **If you have a current or previous diagnosis of Anorexia Nervosa, at what age did this condition onset?**

____

8. **Are you currently undergoing any treatment for Anorexia Nervosa? (e.g. psychiatric treatments, SSRIs, tranquilisers, and or CBT)**

____

9. **Do you have any Neurological or Psychiatric conditions? (For individuals with a current or previous diagnosis of Anorexia Nervosa, do you have any Neurological or Psychiatric conditions in addition to your Anorexia Nervosa diagnosis)?**

   Yes ☐ No ☐

   (If yes, please specify)_________________

10. **Do you have any Chronic pain conditions:**

    Yes ☐ No ☐

    (If yes, please specify)_________________

11. **Please specify your relationship Status:**

    Single ☐

    Engaged ☐

    Married ☐

    Separated ☐

    Divorced ☐

    Widowed ☐

    Other ☐

    (Please specify) _________________

Prefer not to say ☐

12. **Is your Gender you identify with, different to your Sex at birth:**

Yes ☐ No ☐ Prefer not to say ☐

(If Yes, please specify) ________________

13. **Please specify your height:**

____

14. **Please specify your weight:**

____

15. **Please specify your highest level of education:**

High School Graduate ☐

College Graduate ☐

Foundation Degree ☐

Bachelor Degree ☐

Master’s Degree ☐

Doctoral or Professional Degree ☐

Demographics: Study 3

1. **Please specify your Sex:**

   Male ☐

   Female ☐

   Other ☐ (Please specify) ________________

   Prefer not to say ☐

2. **Please specify your Age:**

   ____

3. **Please Specify your ethnicity:**

   White British ☐
   White Irish ☐
   Black Caribbean ☐
   Black African ☐
   Indian ☐
   Pakistani ☐
   Bangladeshi ☐
   White and Black Caribbean ☐
   White and Black African ☐
   White and Asian ☐
   Chinese ☐
   Japanese ☐
   Other ethnic background ☐ (Please specify) _________________

4. **Do you have any Neurological or Psychiatric conditions?**

   Yes ☐ No ☐
   (If yes, please specify)_________________

5. **Do you have any Chronic Skin conditions i.e., Eczema?**

   Yes ☐ No ☐

   (If yes, please specify)________________

6. **Do you have any Chronic pain conditions i.e., Fibromyalgia?**

   Yes ☐ No ☐

(If yes, please specify)________________

7. What is your sexual orientation?

Heterosexual ☐

Homosexual ☐

Bisexual ☐

Asexual ☐

Other ☐

(Please specify) ________________

Prefer not to say ☐

8. Please specify your relationship Status:

Single ☐

Engaged ☐

Married ☐

Separated ☐

Divorced ☐

Widowed ☐

Other ☐

(Please specify) ________________

Prefer not to say ☐

9. Please specify your height:

____

10. Please specify your weight:

____

11. Please specify your highest level of education:

High School Graduate ☐

College Graduate ☐

Foundation Degree ☐

Bachelor Degree ☐

Master's Degree ☐

Doctoral or Professional Degree ☐

12. Are you pregnant?

Yes ☐ No ☐ Not applicable ☐

Demographics: Study 4

<table>
<tr><td colspan="2">AGE:</td><td colspan="2"></td><td rowspan="2">GENDER:</td><td rowspan="2">Male ☐
Female ☐
Other ☐
(If other, please Specify)
__________________</td></tr>
<tr><td colspan="2">DATE OF BIRTH:</td><td colspan="2"></td></tr>
<tr><td>HEIGHT:</td><td></td><td>WEIGHT:</td><td></td><td>BMI:</td><td></td></tr>
<tr><td colspan="6">WHAT IS YOUR ETHNICITY?
Choose one section from (a) to (e) and tick the appropriate box to indicate your cultural background</td></tr>
<tr><td colspan="4">(a) WHITE
☐ British
☐ Irish
☐ Any other White background
please write in below
………………………………</td><td colspan="2">(b) BLACK or BLACK BRITISH
☐ Caribbean
☐ African
☐ Any other Black background
please write in below
…………………………….</td></tr>
<tr><td colspan="4">(c) ASIAN or ASIAN BRITISH
☐ Indian
☐ Pakistani
☐ Bangladeshi
☐ Any other Asian background
please write in below
……………………………..</td><td colspan="2">(d) MIXED
☐ White and Black Caribbean
☐ White and Black African
☐ White and Asian
☐ Any other Mixed background
please write in below
………………………………</td></tr>
<tr><td colspan="4">(e) CHINESE or OTHER ETHNIC GROUP
☐ Chinese
☐ Any other Mixed background
please write in opposite</td><td colspan="2">FOR THE RESEARCHER:
Motor Threshold: __________
mPFC: X__________ Y_________ Z__________
S1: X__________ Y_________ Z__________
Vertex: X__________ Y_________ Z__________</td></tr>
</table>

Appendix 3: MAIA Questionnaire

Below you will find a list of statements. Please indicate how often each statement applies to you generally in daily life.

	NEVER				ALWAYS
1. When I am tense I notice where the tension is located in my body.	0	1	2	3	4
2. I notice when I am uncomfortable in my body.	0	1	2	3	4
3. I notice where in my body I am comfortable.	0	1	2	3	4
4. I notice changes in my breathing, such as whether it slows down or speeds up.	0	1	2	3	4
5. I do not notice (I ignore) physical tension or discomfort until they become more severe.	0	1	2	3	4
6. I distract myself from sensations of discomfort.	0	1	2	3	4
7. When I feel pain or discomfort, I try to power through it.	0	1	2	3	4
8. When I feel physical pain, I become upset.	0	1	2	3	4
9. I start to worry that something is wrong if I feel any discomfort.	0	1	2	3	4
10. I can notice an unpleasant body sensation without worrying about it.	0	1	2	3	4
11. I can pay attention to my breath without being distracted by things happening around me.	0	1	2	3	4
12. I can maintain awareness of my inner bodily sensations even when there is a lot going on around me.	0	1	2	3	4
13. When I am in conversation with someone, I can pay attention to my posture.	0	1	2	3	4
14. I can return awareness to my body if I am distracted.	0	1	2	3	4
15. I can refocus my attention from thinking to sensing my body.	0	1	2	3	4
16. I can maintain awareness of my whole body even when a part of me is in pain or discomfort.	0	1	2	3	4
17. I am able to consciously focus on my body as a whole.	0	1	2	3	4
18. I notice how my body changes when I am angry.	0	1	2	3	4
19. When something is wrong in my life I can feel it in my body.	0	1	2	3	4
20. I notice that my body feels different after a peaceful experience.	0	1	2	3	4
21. I notice that my breathing becomes free and easy when I feel comfortable.	0	1	2	3	4
22. I notice how my body changes when I feel happy / joyful.	0	1	2	3	4
23. When I feel overwhelmed I can find a calm place inside.	0	1	2	3	4
24. When I bring awareness to my body I feel a sense of calm.	0	1	2	3	4
25. I can use my breath to reduce tension.	0	1	2	3	4
26. When I am caught up in thoughts, I can calm my mind by focusing on my body/breathing.	0	1	2	3	4
27. I listen for information from my body about my emotional state.	0	1	2	3	4
28. When I am upset, I take time to explore how my body feels.	0	1	2	3	4
29. I listen to my body to inform me about what to do.	0	1	2	3	4
30. I am at home in my body.	0	1	2	3	4
31. I feel my body is a safe place.	0	1	2	3	4
32. I trust my body sensations.	0	1	2	3	4

Appendix 4: EDE-Q

EATING QUESTIONNAIRE

Instructions: The following questions are concerned with the past four weeks (28 days) only. Please read each question carefully. Please answer all the questions. Thank you.

Questions 1 to 12: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days) only.

.

	On how many of the past 28 days	**No days**	**1-5 days**	**6-12 days**	**13-15 days**	**16-22 days**	**23-27 days**	**Every day**
1	Have you been deliberately <u>trying</u> to limit the amount of food you eat to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
2	Have you gone for long periods of time (8 waking hours or more) without eating anything at all in order to influence your shape or weight?	0	1	2	3	4	5	6
3	Have you <u>tried</u> to exclude from your diet any foods that you like in order to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
4	Have you <u>tried</u> to follow definite rules regarding your eating (for example, a calorie limit) in order to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
5	Have you had a definite desire to have an <u>empty</u> stomach with the aim of influencing your shape or weight?	0	1	2	3	4	5	6
6	Have you had a definite desire to have a <u>totally flat</u> stomach?	0	1	2	3	4	5	6
7	Has thinking about <u>food, eating or calories</u> made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?	0	1	2	3	4	5	6
8	Has thinking about <u>shape or weight</u> made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?	0	1	2	3	4	5	6
9	Have you had a definite fear of losing control over eating?	0	1	2	3	4	5	6
10	Have you had a definite fear that you might gain weight?	0	1	2	3	4	5	6
11	Have you felt fat?	0	1	2	3	4	5	6
12	Have you had a strong desire to lose weight?	0	1	2	3	4	5	6

Questions 13-18: Please fill in the appropriate number in the boxes on the right. Remember that the questions only refer to the past four weeks (28 days).

Over the past four weeks (28 days) ……

13	Over the past 28 days, how many times have you eaten what other people would regard as an unusually large amount of food (given the circumstances)?	……………..
14	….. On how many of these times did you have a sense of having lost control over your eating (at the time that you were eating)?	……………..
15	Over the past 28 days, on how many **DAYS** have such episodes of overeating occurred (i.e., you have eaten an unusually large amount of food and have had a sense of loss of control at the time)?	……………..
16	Over the past 28 days, how many times have you made yourself sick (vomit) as a means of controlling your shape or weight?	……………..
17	Over the past 28 days, how many times have you taken laxatives as a means of controlling your shape or weight?	……………..
18	Over the past 28 days, how many times have you exercised in a "driven" or "compulsive" way as a means of controlling your weight, shape or amount of fat, or to burn off calories?	……………..

Questions 19 to 21: Please circle the appropriate number. Please note that for these questions the term "binge eating" means eating what others would regard as an unusually large amount of food for the circumstances, accompanied by a sense of having lost control over eating.

19	Over the past 28 days, on how many days have you eaten in secret (ie, furtively)? ….. Do not count episodes of binge eating	No days	1-5 days	6-12 days	13-15 days	16-22 days	23-27 days	Every day
		0	1	2	3	4	5	6
20	On what proportion of the times that you have eaten have you felt guilty (felt that you've done wrong) because of its effect on your shape or weight? ….. Do not count episodes of binge eating	None of the times	A few of the times	Less than half	Half of the times	More than half	Most of the time	Every time
		0	1	2	3	4	5	6
21	Over the past 28 days, how concerned have you been about other people seeing you eat? ….. Do not count episodes of binge eating	Not at all		Slightly		Moderately		Markedly
		0	1	2	3	4	5	6

Questions 22 to 28: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days).

	Over the past 28 days	**Not at all**		**Slightly**		**Moderate -ly**		**Markedly**
22	Has your weight influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
23	Has your shape influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
24	How much would it have upset you if you had been asked to weigh yourself once a week (no more, or less, often) for the next four weeks?	0	1	2	3	4	5	6
25	How dissatisfied have you been with your weight?	0	1	2	3	4	5	6
26	How dissatisfied have you been with your shape?	0	1	2	3	4	5	6
27	How uncomfortable have you felt seeing your body (for example, seeing your shape in the mirror, in a shop window reflection, while undressing or taking a bath or shower)?	0	1	2	3	4	5	6
28	How uncomfortable have you felt about others seeing your shape or figure (for example, in communal changing rooms, when swimming, or wearing tight clothes)?	0	1	2	3	4	5	6

What is your weight at present? (Please give your best estimate.) ....

What is your height? (Please give your best estimate.) ....

If female: Over the past three-to-four months have you missed any menstrual periods? ....

If so, how many? ....

Have you been taking the "pill"? ....

THANK YOU

Appendix 5: EDI-3

Weight = ……………………. Height = …………………….

DOB = ……………………. Age = ……………….

Complete the questionnaire by putting a cross (X) or highlight the answer (A U O S R N) that you find the most descriptive of your behaviours and your thinking

A = ALWAYS, U = USUALLY, O = OFTEN, S = SOMETIMES, R = RARELY, N = NEVER

1. I eat sweets and carbohydrates without feeling nervous	A	U	O	S	R	N
2. I think that my stomach is too big	A	U	O	S	R	N
3. I wish that I could return to the security of childhood	A	U	O	S	R	N
4. I eat when I am upset	A	U	O	S	R	N
5. I stuff myself with food	A	U	O	S	R	N
6. I wish that I could be younger	A	U	O	S	R	N
7. I think about dieting	A	U	O	S	R	N
8. I get frightened when my feelings are too strong	A	U	O	S	R	N
9. I think that my thighs are too large	A	U	O	S	R	N
10. I feel ineffective as a person	A	U	O	S	R	N
11. I feel extremely guilty after overeating	A	U	O	S	R	N
12. I think that my stomach is just the right size	A	U	O	S	R	N
13. Only outstanding performance is good enough in my family	A	U	O	S	R	N
14. The happiest time in life is when you are a child	A	U	O	S	R	N
15. I am open about my feelings	A	U	O	S	R	N
16. I am terrified of gaining weight	A	U	O	S	R	N
17. I trust others	A	U	O	S	R	N
18. I feel alone in the world	A	U	O	S	R	N
19. I feel satisfied with the shape of my body	A	U	O	S	R	N
20. I feel generally in control of things of my life	A	U	O	S	R	N

21. I get confused about the emotions I am feeling	A	U	O	S	R	N
22. I would rather be an adult than I child	A	U	O	S	R	N
23. I can communicate with others easily	A	U	O	S	R	N
24. I wish I were somewhere else	A	U	O	S	R	N
25. I exaggerate or magnify the importance of weight	A	U	O	S	R	N
26. I can clearly identify what emotions I am feeling	A	U	O	S	R	N
27. I feel inadequate	A	U	O	S	R	N
28. I have gone on eating binges where I felt that I could not stop	A	U	O	S	R	N
29. As I child, I tried very hard to avoid disappointing my parents and teachers	A	U	O	S	R	N
30. I have close relationships	A	U	O	S	R	N
31. I like the shape of my buttocks	A	U	O	S	R	N
32. I am preoccupied with the desire to be thinner	A	U	O	S	R	N
33. I don't know what's going on inside me	A	U	O	S	R	N
34. I have troubles expressing my emotions to others	A	U	O	S	R	N
35. The demands of adulthood are too great	A	U	O	S	R	N
36. I hate being less than best at things	A	U	O	S	R	N
37. I feel secure about myself	A	U	O	S	R	N
38. I think about bingeing (overeating)	A	U	O	S	R	N
39. I feel happy that I am not a child anymore	A	U	O	S	R	N
40. I get confused as to whether or not I am hungry	A	U	O	S	R	N
41. I have a low opinion of myself	A	U	O	S	R	N
42. I feel that I can achieve my standards	A	U	O	S	R	N
43. My parents have expected excellence of me	A	U	O	S	R	N
44. I worry that my feelings will get out of control	A	U	O	S	R	N
45. I think my hips are too big	A	U	O	S	R	N
46. I eat moderately in front of others and stuff myself when they are gone	A	U	O	S	R	N
47. I feel bloated after eating a normal meal	A	U	O	S	R	N

48. I feel that people are happiest when they are children	A	U	O	S	R	N
49. If I gain a pound, I worry that I will keep gaining	A	U	O	S	R	N
50. I feel that I am a worthwhile person	A	U	O	S	R	N
51. When I am upset, I don't know if I am sad, frightened or angry	A	U	O	S	R	N
52. I feel that I must do things perfectly or not do them at all	A	U	O	S	R	N
53. I have the thought of trying to vomit in order to lose weight	A	U	O	S	R	N
54. I need to keep people at a certain distance (feel uncomfortable if someone tries to get too close)	A	U	O	S	R	N
55. I think that my thighs are just the right size	A	U	O	S	R	N
56. I feel empty inside	A	U	O	S	R	N
57. I can talk about personal thoughts and feelings	A	U	O	S	R	N
58. The best years of your life are when you become an adult	A	U	O	S	R	N
59. I think that my buttocks are too large	A	U	O	S	R	N
60. I have feelings I can't quite identify	A	U	O	S	R	N
61. I eat or drink in secrecy	A	U	O	S	R	N
62. I think that my hips are just the right size	A	U	O	S	R	N
63. I have extremely high goals	A	U	O	S	R	N
64. When I am upset , I worry that I will start eating	A	U	O	S	R	N
65. People I really like end up disappointing me	A	U	O	S	R	N
66. I am ashamed of my human weaknesses	A	U	O	S	R	N
67. Other people would say that I am emotionally instable	A	U	O	S	R	N
68. I would like to be in total control of my bodily urges	A	U	O	S	R	N
69. I feel relaxed in most group situations	A	U	O	S	R	N
70. I say things impulsively that I regret having said	A	U	O	S	R	N
71. I would do anything to feel pleasure	A	U	O	S	R	N
72. I have to be careful in my tendency to abuse drugs	A	U	O	S	R	N
73. I am outgoing with most people	A	U	O	S	R	N

74. I feel trapped in relationships	A	U	O	S	R	N
75. Self denials makes me feel stronger spiritually	A	U	O	S	R	N
76. People understand my real problems	A	U	O	S	R	N
77. I can’t get strange thoughts out of my head	A	U	O	S	R	N
78. Eating for pleasure is a sign of moral weakness	A	U	O	S	R	N
79. I am prone to outburst of anger or rage	A	U	O	S	R	N
80. I feel that people give me the credit I deserve	A	U	O	S	R	N
81. I have to be careful in my tendency to abuse alcohol	A	U	O	S	R	N
82. I believe that relaxing is simply a waste of time	A	U	O	S	R	N
83. Others would say that I get irritate easily	A	U	O	S	R	N
84. I feel like I am losing out everywhere	A	U	O	S	R	N
85. I experience marked mood swings	A	U	O	S	R	N
86. I am embarrassed by my body urges	A	U	O	S	R	N
87. I would rather spend time by myself than with others	A	U	O	S	R	N
88. Suffering makes you a better person	A	U	O	S	R	N
89. I know that people love me	A	U	O	S	R	N
90. I feel like I must hurt myself or others	A	U	O	S	R	N
91. I feel that I really know who I am	A	U	O	S	R	N

Appendix 6: DCQ

Have you ever:

1) Been very concerned about some aspect of your physical appearance?

Not at all   Same as most people   More than most people   Much more than most people

2) Considered yourself misformed or mishapen in some way (e.g. nose/hair/skin/sexual organs/overall body build).

Not at all   Same as most people   More than most people   Much more than most people

3) Considered your body to be malfunctional in some way (e.g. excessive body odour, flatulence, sweating).

Not at all   Same as most people   More than most people   Much more than most people

4) Consulted or felt you needed to consult a plastic surgeon/dermatologist/physician about these concerns.

Not at all   Same as most people   More than most people   Much more than most people

5) Been told by others/doctor that you are normal in spite of you strongly believing that something is wrong with your appearance or bodily functioning.

Not at all   Same as most people   More than most people   Much more than most people

6) Spent a lot of time worrying about a defect in your appearance/bodily functioning.

Not at all   Same as most people   More than most people   Much more than most people

7) Spent a lot of time covering up defects in your appearance/bodily functioning

Not at all   Same as most people   More than most people   Much more than most people

Appendix 7: TEAQ

	Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree Strongly
1. I dislike people being very physically affectionate towards me					
2. I like using body lotions					
3. I have to know someone quite well to enjoy a hug from them					
4. I find it natural to greet my friends and family with a kiss on the cheek					
5. There was a lot of physical affection during my childhood					
6. As a child I would often hug family members					
7. I like to use bath essence when having a bath					
8. I find stroking the hair of a person I am fond of very pleasurable					
9. My parents were not very physically affectionate towards me during my childhood					
10. I like to fall asleep in the arms of someone I am close to					
11. I often snuggle up on the sofa with someone					
12. I enjoy the physical intimacy of sexual foreplay					
13. I like to link arms with my friends and family as I walk along					
14. I usually hug my family and friends when I am saying goodbye					
15. As a child I found a hug from my parents when I was upset made me feel much happier					
16. It's nice when friends and family members greet me with a kiss					
17. I often hold hands with someone I know intimately					
18. When I am upset, there is usually someone who can comfort me					
19. Kissing is a great way of expressing physical attraction					
20. It feels really good when someone I am fond of runs their fingers through my hair					
21. I regularly hug people I am close to					

22. As a child my parents would tuck me up in bed every night and give me a hug and a kiss goodnight					
23. My life lacks physical affection					
24. I enjoy having my skin stroked					
25. I often take a shower or bath with someone					
26. I enjoy having sex					
27. I often have sex					
28. I am put off by physical familiarity					
29. I can always find somebody to physically comfort me when I am upset					
30. I always greet my friends and family by giving them a hug					
31. I enjoy being cuddled by someone I am fond of					
32. My mother regularly bathed me as a child					
33. As a child my parents always comforted me when I was upset					
34. I enjoy the feeling of my skin against someone else's if I know them intimately					
35. As a child my parents would often hold my hand when I was walking along with them					
36. Most days I get a hug or a kiss					
37. If someone I don't know very well puts a friendly hand on my arm it makes me feel uncomfortable					
38. I often make physical contact with my friends and family when I am with them					
39. It makes me feel uncomfortable if someone I don't know very well touches me in a friendly manner					
40. I enjoy holding hands with someone I am fond of					
41. I often share a romantic kiss					
42. As a child my mother regularly brushed my hair					
43. I like exfoliating my skin					
44. Kissing is an enjoyable part of expressing romantic feeling					
45. I often have my skin stroked					
46. I often hold hands with someone I am fond of					
47. I like to stroke the skin of someone I know intimately					
48. I am on huggable terms with quite a few people					

49. I often fall asleep while holding someone I am close to					
50. Snuggling up on the sofa with someone is great					
51. I often put my arm around a close friend as we walk along together					
52. I like having a bath with lots of bubble bath					
53. I don't get many hugs these days					
54. I am often given a shoulder massage					
55. I like to use face masks on my skin					
56. I like it when my friends and family greet me by giving me a hug					
57. I often link arms with my friends and family as I walk along					

Appendix 8: Covid-19 Questionnaire

Please read and provide an answer to the following questions below. These questions concern your touch experiences, eating behaviours, physical activity rate and feelings of social isolation since the current COVID-19 situation. Please be as accurate as possible with your answers.

1. **What country do you currently live in?**

   ____

2. **Is the country you live in, currently in lockdown?**

   Yes (if yes, please state for how long)

   ____

   No

3. **Do you consider yourself at high risk of contracting COVID-19?**

   Yes
   No
   Unsure

4. **To what extent has the level of touch you give to people within your household reduced since COVID-19?**

   Not at all____Extremely

   Comments (optional)

5. **To what extent has the level of touch you receive from people within your household reduced since COVID-19?**

   Not at all____Extremely

   Comments (optional)

6. To what extent has the level of touch you give to a stranger reduced since COVID-19?

Not at all____Extremely

Comments (optional)

7. To what extent has the level of touch you receive from a stranger reduced since COVID-19?

Not at all____Extremely

Comments (optional)

8. Overall, since COVID-19, my level of touch with individuals has reduced.

Not at all____Extremely

Comments (optional)

9. Currently, I want to be:

Touched by others less__________________________________Touched by others more

Comments (optional)

10. Since COVID-19, how would you best describe your eating behaviours?

Eating less____Eating more

Comments (optional)

11. Since COVID-19, my physical activity rates has:

Decreased____Increased

Comments (optional)

12. Since COVID-19, I am feeling a great deal of social isolation from my usual support networks i.e. family and friends.

Not at all____Extremely

Comments (optional)

Appendix 9: TMS Safety Screening Questionnaire

Confidential

Before receiving Transcranial Stimulation, please read the questions below carefully and provide answers. For a small number of individuals, brain stimulation may carry an increased risk of causing a seizure. The purpose of these questions is to make sure that you are not such a person. You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will be held in secure conditions. If you are unsure of the answer to any of the questions, please ask the person who gave you this form or the person who will be performing the study.

1. Do you have epilepsy or have you ever had a convulsion or a seizure (fit)?	**YES**	**NO**
Has anyone in your immediate or distant family suffered from seizures? If YES please state your relationship to the affected family member. …………………………………..	**YES**	**NO**
2. Have you ever had a fainting spell or syncope? If yes, please describe on which occasion(s)? …………………………………..	**YES**	**NO**
3. Have you ever had a head trauma that was diagnosed as a concussion or was associated with loss of consciousness?	**YES**	**NO**
4. Do you have any hearing problems or ringing in your ears?	**YES**	**NO**
5. Do you have cochlear implants?	**YES**	**NO**
6. Are you pregnant or is there any chance that you might be?	**YES**	**NO**
7. Do you have metal in the brain, skull or elsewhere in your body (e.g., splinters, fragments, clips, etc.)?	**YES**	**NO**
8. Do you have an implanted neurostimulator (e.g., DBS, epidural/subdural, VNS)?	**YES**	**NO**
9. Do you have a cardiac pacemaker or intracardiac lines?	**YES**	**NO**
10. Do you have a medication infusion device?	**YES**	**NO**
11. Are you taking any prescribed or unprescribed medications (or herbal remedies)? (Please list) …………………………………..	**YES**	**NO**
12. Did you ever undergo TMS in the past? If YES, please state if there were any problems and describe them. …………………………………..	**YES**	**NO**
When was your last brain stimulation (TCS, TMS) session? ………………………………….. How many brain stimulation sessions have you had in the past month? ………………………………….. How many brain stimulation sessions have you had in the past 12 months? …………………………………..		

13. Did you ever undergo MRI in the past? If so, were there any problems. …………………………………..	**YES**	**NO**
14. Have you ever undergone a neurosurgical procedure (including eye surgery)? If YES, please give details: …………………………………..	**YES**	**NO**
15. Are you currently undergoing anti-malarial treatment?	**YES**	**NO**
16. Have you drunk more than 3 units of alcohol in the last 24 hours?	**YES**	**NO**
17. Have you drunk alcohol already today?	**YES**	**NO**
18. Have you had more than one cup of coffee, or other sources of caffeine, in the last hour?	**YES**	**NO**
19. Have you used recreational drugs in the last 24 hours?	**YES**	**NO**
20. Did you have very little sleep last night?	**YES**	**NO**

I understand that the above questions check for serious risk factors.
I CONFIRM THAT I HAVE READ, UNDERSTOOD AND CORRECTLY ANSWERED THE ABOVE QUESTIONS.

IN CASE OF ANY DOUBT, please inform the investigator before signing this form.

Participant

Signed ……………………………………….. NAME IN BLOCK LETTERS …..……………………………………. Date …………………………………………

Researcher

Signed ……………………………………….. NAME IN BLOCK LETTERS …..……………………………………. Date …………………………………………

Please note: All data arising from this study will be held and used in accordance with the Data Protection Act (1984). The results of the study will not be made available in a way that could reveal the identity of individuals.

(Based on Screening13-item Questionnaire for brain stimulation Candidates recommended by Rossi, Hallett, Rossini and Pascual-Leone 2011; updated 15/02/12)

You do not have to answer any questions you do not feel comfortable with. Once you have completed the questionnaire you are asked to send it back to (A.M.Bellard@2020.ljmu.ac.uk). We kindly ask you to send it back within one week.

Appendix 10: Covid-19 correlational analysis (Study 1)

For exploratory purposes, the association with touch avoidance and social isolation due to Covid-19 with pleasant touch awareness index (PTA) was conducted for each group (high and low EDs risk) and calculated separately per task.

For high EDs risk and self-directed touch, Covid-19 subscales (Given in household, received in household, given to stranger, received from stranger, level of touch reduced, touch wanting, eating behaviours, physical activity rate and social isolation) were not significantly associated with PTA for the upper arm (*all rs* > -.092, *ps* > .113), ventral forearm *all rs* > -.296, *ps* > .054), back (*all rs* > -.221, *ps* > .165), cheek (*all rs* > -.234, *ps* > .122) and palm (*all rs* > -.249, *ps* > .100).

For other-directed touch, Covid-19 subscales were not significantly associated with PTA for high EDs risk for the upper arm (*all rs* > -.169, *ps* > .057), ventral forearm (*all rs* > -.210, *ps* > .177), back (*all rs* > -.184, *ps* > .226) and palm (*all rs* > -.155, *ps* > .310). For the cheek, although there was a marginally significant association with eating behaviours (r = .297, p = .047), after a Bonferroni correction, this significance value was no longer significant. All other Covid-19 subscales were not significant for the cheek (*all rs* > -.260, *ps* > .085).

For low EDs risk and self-directed touch, Covid-19 subscales (Given in household, received in household, given to stranger, received from stranger, level of touch reduced, touch wanting, eating behaviours, physical activity rate and social isolation) were not significantly associated with PTA for the upper arm (*all rs* > -.175, *ps* > .053), ventral forearm *all rs* > -.167, *ps* > .302), back (*all rs* > -.064, *ps* > .105) and palm (*all rs* > -.250, *ps* > .120). For the cheek, although there was a marginally significant association with touch received in the household (r = .322, p = .043), after a Bonferroni correction, this significance value was no longer significant. All other Covid-19 subscales were not significant for the cheek (*all rs* > -.214, *ps* > .186).

For other-directed touch, Covid-19 subscales were not significantly associated with PTA for low EDs risk for the upper arm (*all rs* > -.037, *ps* > .089), ventral forearm (*all rs* > -.287, *ps* > .073), back (*all rs* > -.212, *ps* > .190), cheek (*all rs* > -.203, *ps* > .294) and palm (*all rs* > -.107, *ps* > .512).

To summarise, pleasantness of CT-optimal touch to individual body parts for self-directed touch and other-directed touch was not influenced by Covid-19 subscales for both high EDs risk and low EDs risk.

Appendix 11: Gender Analysis – Study 3 (Supplementary materials; Bellard et al., 2023)

Demographics and self-report scales

Table 1 displays the means and standard deviations for age and questionnaire subscales, which have been calculated separately for males and females. The third column in the table shows the results of a series of pairwise comparisons between the two gender groups (Bonferroni-corrected). Both groups did not significantly differ in age. However, both males and females differed regarding EDI-3 subscale scores, with males having marginally significantly higher drive for thinness and higher eating disorder composite risk. Males demonstrated significantly higher Perfectionism and Ascetism. Males and females did not differ in body dissatisfaction, Bulimia, low self-esteem, interpersonal alienation, emotional dysregulation, maturity fear, personal alienation, interpersonal insecurity, and interoceptive deficits. Females displayed higher levels of dysmorphic concerns as measured by the DCQ compared to males (see Table 1).

Table 1. Mean and standard deviation (in brackets) of demographics and self-report questionnaires scores for Males (*n*= *22*) compared to Females (*n*=*47*).

	Males (*n*=*22*)	Females (*n*= *47*)	Males vs. Females
Age	29.55 (13.68)	27.55 (10.04)	*t*(67) = .682, p =.498
EDI-3			
Drive for thinness	13.00 (9.26)	9.00 (7.35)	*t*(67) = 1.936, p = .057
Body dissatisfaction	20.59 (10.55)	16.09 (11.07)	*t*(67) = 1.599, p = .115
Bulimia	15.59 (12.46)	11.36 (9.94)	*t*(67) = 1.517, p = .134

Low self esteem	10.91 (7.85)	9.26 (6.77)	*t*(67) = .899, p = .372
Interpersonal alienation	11.86 (7.97)	9.34 (6.13)	*t*(67) = 1.445, p = .153
Emotional dysregulation	12.09 (11.31)	9.98 (8.76)	*t*(67) = .849, p = .399
Perfectionism	12.82 (5.16)	9.04 (4.53)	*t*(67) = 3.086, p = .003
Ascetism	13.59 (8.87)	8.96 (7.72)	*t*(67) = 2.215, p = .030
Maturity fear	12.95 (7.45)	11.94 (7.29)	*t*(67) = .537, p = .593
Personal alienation	13.64 (8.72)	10.02 (7.33)	*t*(67) = 1.796, p = .077
Interpersonal insecurity	12.59 (6.49)	10.68 (6.47)	*t*(67) = 1.142, p = .258
Interoceptive deficit	16.05 (11.59)	11.47 (9.89)	*t*(67) = 1.695, p = .095
EDRC	49.18 (30.44)	36.45 (22.86)	*t*(67) = 1.935, p = .057
DCQ	12.23 (5.07)	15.66 (5.95)	*t*(67) = -2.337, p = .022

Notes: *EDI-3* Eating Disorder Inventory 3; *EDRC* Eating Disorder Risk Composite; *DCQ* Dysmorphic Concern Questionnaire.

Main Analyses

Imagined Social Touch ratings: Intimate vs. Social Body Regions

The 4-way mixed ANOVA of Body Zone (Intimate vs. Social) × Relationship (Loved one vs. Acquaintance) × Group (High BIDS vs. Low BIDs) × Gender (Males vs. Females) on the soothing/unpleasantness ratings revealed a significant main effect of Body Zone [$F(1,65) = 94.595$, $p < .001$, $\eta p^2 = .593$] and a main effect of Relationship [$F(1,65) = 129.926$, $p < .001$, $\eta p^2 = .667$]. These main effects were further qualified by a significant 2-way interaction between Body Zone × Relationship [$F(1,65) = 25.301$, $p < .001$, $\eta p^2 = .280$]. Post-hoc comparisons revealed that, when received by a loved one, touch to social regions was significantly rated as more soothing than touch to intimate regions (41.94 ± 4.43 vs. 29.47 ± 5.60, $p < .001$). On the other hand, when received by an acquaintance, touch to intimate regions was significantly rated as more unpleasant than touch to social regions (-47.47 ± 4.27 vs. -16.19 ± 4.06, $p < .001$). Furthermore, touch to intimate regions received from a loved one was rated as significantly more soothing than that received from an acquaintance, which was rated as unpleasant (29.47 ± 5.60 vs. -47.47 ± 4.27, $p < .001$). Touch to social regions were rated as significantly more soothing when provided from a loved one as opposed to an acquaintance which were rated as unpleasant (41.94 ± 4.43 vs. -16.19 ± 4.06, $p < .001$, see Fig. S1).

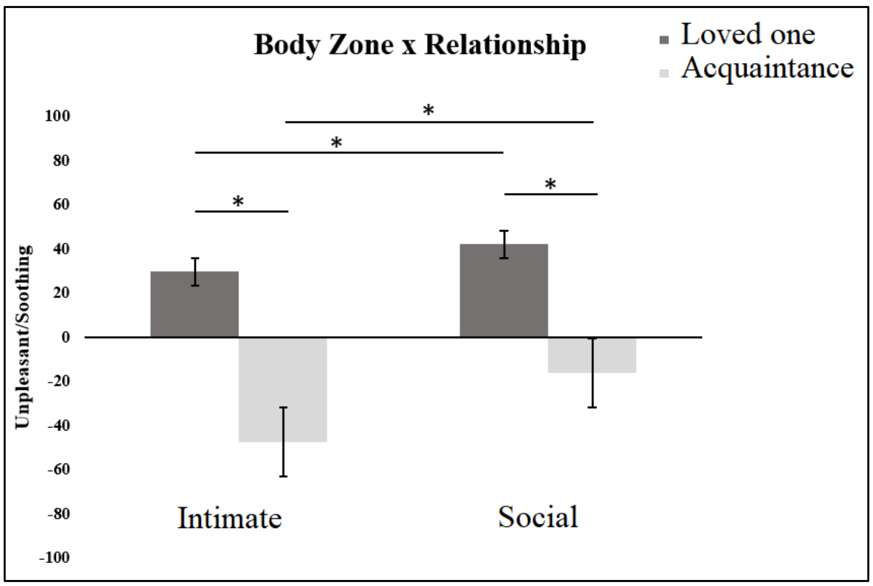

Fig. S1: Mean (M) and Standard Error of the Mean (S.E.M.) for soothing/unpleasant ratings for imagined touch delivered to each bodily regions (intimate vs. social) and for each relationship (loved one vs acquaintance).

A significant main effect of Gender was also revealed [$F(1, 65) = 5.603$, $p=.021$, $\eta p^2 = .079$], which was further qualified by a significant 2-way interaction of Body Zone × Gender [$F(1, 65) = 10.972$, $p=.002$, $\eta p^2 = .144$]. Post-hoc comparisons revealed that both females and males always rated touch to social areas as more soothing than touch received to intimate body areas. However, whilst no gender difference was found for touch received to social areas (females: 8.93 ± 3.67 vs. males: 16.82 ± 5.38, $p = .21$), on the contrary females rated touch to intimate areas as less pleasant than males did (females: -20.39 ± 4.05 vs. males: 2.39 ± 5.94, $p < .001$, see Fig. S2).

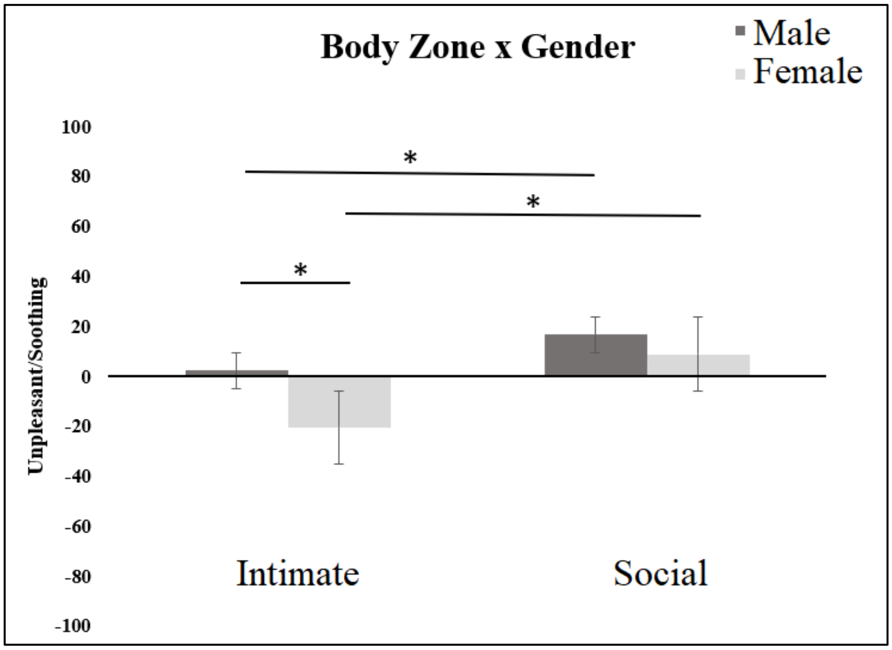

Fig. S2: Mean (M) and Standard Error of the Mean (S.E.M.) for soothing/unpleasant ratings for imagined touch delivered to each bodily regions (intimate vs. social) and for each gender group (male vs female).

Finally, no interaction between Group and Gender was significant, thus suggesting that females and males did not differ in their pleasantness ratings depending on their levels of BIDs. Finally, the remaining effects were all non-significant [All $Fs < 3.656$, $p > 0.06$, $\eta p2 < 0.053$].