

Ana Rita Soares Pereira

Affective Touch and Individual Differences: Evidence from Neurotypical and Autistic Individuals

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Affective Touch and Individual Differences: Evidence from Neurotypical and Autistic Individuals

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Trabalho efetuado sob a orientação do
Doutor Alberto Jacobo González Villar
e da
Professora Doutora Adriana da Conceição Soares Sampaio

maio de 2026

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Statement of Integrity

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Toque Afetivo e Diferenças Individuais: Evidência de Indivíduos Neurotípicos e com Perturbação do Espetro do Autismo

Resumo

O toque afetivo, mediado por aferentes C-Táteis (CT), é um canal essencial de comunicação interpessoal e regulação emocional. Embora as propriedades discriminativas do sistema somatossensorial tenham sido amplamente estudadas, evidências crescentes destacam o papel crucial do sistema CT nos comportamentos afiliativos e no bem-estar. No entanto, pouco se sabe sobre como o toque direcionado para as fibras CT é percebido e processado entre indivíduos, ou como estes processos são moldados por experiências táteis prévias e características socioafetivas. Esta dissertação abordou estas lacunas através de uma abordagem multidimensional do toque que combina validação psicométrica, paradigmas comportamentais e medidas neurofisiológicas. Primeiro, validámos a versão para Português Europeu do Questionário de Experiências e Atitudes Tácteis (TEAQ), um instrumento de autorrelato que apresentou boas propriedades psicométricas e replicou a estrutura original de seis fatores. Os três estudos empíricos subsequentes exploraram os correlatos comportamentais e neurofisiológicos do toque otimizado para as fibras CT. O primeiro estudo explorou as dinâmicas oscilatórias cerebrais durante a estimulação CT-ótima versus discriminativa em adultos neurotípicos. O toque CT-ótimo revelou maior dessincronização de alfa/mu e beta, sugerindo uma maior excitabilidade sensório-motora e envolvimento atencional. A análise dos microestados também demonstrou configurações temporais da atividade cerebral distintas entre as duas condições. O segundo estudo investigou os correlatos neurais durante a observação do toque CT-ótimo em adultos neurotípicos. O toque CT-ótimo foi percecionado como mais agradável e socialmente relevante e provocou maior dessincronização de beta do que o toque estático e rápido, indicando o recrutamento de processos sensório-motores mesmo na ausência de contacto físico. Por fim, estendemos o paradigma a adolescentes e jovens adultos com Perturbação do Espectro do Autismo (PEA), que exibiram respostas hedónicas ao toque observado semelhantes aos participantes neurotípicos, apesar de apresentarem pontuações mais baixas nas medidas de empatia e relacionadas com o toque. Este padrão sugere que a sociabilidade reduzida reportada na PEA pode decorrer de fatores interpretativos de nível superior, em vez de défices na perceção das qualidades afetivas do toque. Em conclusão, estas descobertas fornecem evidências convergentes de que o toque afetivo, quer seja direto ou observado, constitui um mecanismo fundamental no processamento socioafetivo. Ao integrar medidas psicométricas, comportamentais e neurais, este trabalho contribui para uma compreensão mais abrangente de como o toque CT-ótimo sustenta a conexão social, no desenvolvimento típico e atípico.

Palavras-chave: Aferentes C-Táteis; Perturbação do Espectro do Autismo; Psicofisiologia; Toque Afetivo.

Affective Touch and Individual Differences: Evidence from Neurotypical and Autistic Individuals

Abstract

Affective touch, mediated by unmyelinated C-Tactile (CT) afferents, is a key channel of interpersonal communication and emotional regulation. Although the discriminative properties of the somatosensory system have been widely studied, growing evidence highlights the CT system as crucial for affiliative behaviours, social bonding, and well-being. However, little is known about how CT-targeted touch is perceived and processed across individuals and how these processes are shaped by previous tactile experiences and socio-affective traits. This dissertation addressed these gaps through a multidimensional approach of touch combining psychometric validation, behavioural paradigms, and neurophysiological measures. First, we validated the European Portuguese version of the Touch Experiences and Attitudes Questionnaire (TEAQ), a self-report measure of individual differences in tactile experiences and attitudes toward touch. This version showed good psychometric properties and replicated the original six-factor structure. Then, three experimental studies explored behavioural and neurophysiological correlates of CT-targeted touch. The first empirical study aimed to explore the brain oscillatory dynamics during CT-optimal versus discriminative (vibrotactile) stimulation in neurotypical adults. Results revealed a greater alpha/mu and beta desynchronisation for CT-targeted stroking, suggesting increased sensorimotor excitability and attentional engagement. Microstate analysis also showed distinct temporal configurations of global brain activity between the two conditions. The second empirical study investigated the brain correlates during the observation of CT-targeted touch videos in neurotypical adults. Results found that CT-optimal stroking was perceived as more pleasant and socially relevant and elicited greater beta desynchronisation than static or fast touch, indicating recruitment of sensorimotor processes even in the absence of real physical contact. In our last study, we extended this paradigm to adolescents and young adults with autism spectrum disorder (ASD), who exhibited similar hedonic responses to observed touch as neurotypical participants, despite scoring lower on empathy and touch-related measures. This pattern suggests that the reduced sociability reported in ASD may stem from higher-level interpretative factors rather than from deficits in perceiving the affective qualities of touch. In sum, the findings of the present dissertation provide converging evidence that affective touch, whether directly experienced or observed, constitutes a key mechanism in socio-affective processing. By integrating psychometric, behavioural, and neural measures, this work contributes to a more comprehensive understanding of how CT-mediated touch supports social connection, both in typical and atypical development.

Keywords: Affective Touch; Autism Spectrum Disorder; C-Tactile Afferents; Psychophysiology.

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Abbreviations

A	Agreeableness
Aβ	A-beta
Aδ	A-delta
Ag	Silver
AgCl	Silver Chloride
AIC	Akaike Information Criterion
AIT	Attitude To Intimate Touch
ANOVA	Analysis Of Variance
ASC	Attitude To Self-Care
ASD	Autism Spectrum Disorder
AUT	Attitude To Unfamiliar Touch
BES	Basic Empathy Scale
C	Conscientiousness
CBCL	Child Behaviour Checklist
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
ChT	Childhood Touch
CIT	Current Intimate Touch
C-LTMR	C Low-Threshold Mechanosensitive Receptors
CMS	Common Mode Sense
COVID-19	Coronavirus Disease 2019
CT	C-Tactile
DIF	Differential Item Functioning
DLR	Driven Right Leg
DNA	Deoxyribonucleic Acid
DSM	Diagnostic And Statistical Manual Of Mental Disorders
E	Extraversion
EEG	Electroencephalography
ERD	Event-Related Desynchronisation
ERP	Event-Related Potential

FDR	False Discovery Rate
FFT	Friends And Family Touch
FIR	Finite Impulse Response
fMRI	Functional Magnetic Resonance Imaging
GEV	Global Explained Variance
GFI	Goodness-Of-Fit Index
GFP	Global Field Power
HEOG	Horizontal Electrooculogram
ICA	Independent Components Analysis
KMO	Kaiser-Meyer-Olkin
LPP	Late Positive Potential
LRA	Linear Resonant Actuator
M	Mean
MNSQ	Mean Square
mPFC	Medial Prefrontal Cortex
MS	Microstates
N	Neuroticism
NEO-FFI	Neo Five-Factor Inventory
NFI	Normed Fit Index
NRS	Numeric Rating Scales
O	Openness To Experience
OFC	Orbitofrontal Cortex
PSD	Power Spectral Density
pSTS	Posterior Superior Temporal Sulcus
PV	Plausible Values
RIAS	Reynolds Intellectual Assessment Scales
RMSEA	Root Mean Square Error Of Approximation
SD	Standard Deviation
SE	Standard Error
SI	Primary Somatosensory Cortex
SII	Secondary Somatosensory Cortex
SIPAAS	Social Interaction And Performance Anxiety And Avoidance Scale

STQ	Social Touch Questionnaire
TANOVA	Topographical Analysis Of Variance
TEAQ	Touch Experiences And Attitudes Questionnaire
VEOG	Vertical Electrooculogram
vlPFC	Ventrolateral Prefrontal Cortex
WAIS	Wechsler Adult Intelligence Scale
WISC	Wechsler Intelligence Scale For Children
WPPSI	Wechsler Preschool And Primary Scale Of Intelligence
y	Years

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CHAPTER 1

General Introduction

Chapter 1. General Introduction

"*Touch comes before sight, before speech.*
It is the first language and the last, and it always tells the truth."
(Margaret Atwood, 2000)

1.1. Introduction

Touch is a crucial means through which humans engage with the world, allowing us to gather insights about the external environment. Beyond its sensory function, it is also a fundamental channel for social interaction and socio-affective functioning (Cascio et al., 2019; McGlone et al., 2014; Morrison et al., 2010). The social dimensions of touch are relevant across numerous domains of human behaviour, ranging from cultural anthropology to neuroscience.

This central role of touch emerges early in development. As the first sensory modality to develop during fetal development (Montagu, 1978), with embryo at approximately six weeks of gestation already capable of responding to a variety of tactile stimulation (Bremner et al., 2012; Stratton, 1983). It is the most developed sense at birth, being one of the earliest channels of communication and engagement with the environment and playing a fundamental role in emotional regulation and early social bonding (Stratton, 1983). Across the lifespan, tactile interactions contribute to the development and maintenance of social relationships and, thereby, to our physical and psychological well-being (Cascio et al., 2019; Morrison et al., 2010; Walker & McGlone, 2013). Touch is therefore intimately linked to social bonding, fostering affiliative, collaborative, and intimate behaviours, and playing a critical role in communication and in conveying social support, for instance through gentle stroking (Suvilehto et al., 2015). Despite its fundamental role in human functioning, touch is one of the least well-known of the human sensory modalities, particularly in contrast to the visual and auditory systems, which have dominated research in social neuroscience as primary channels for social information processing (Gallace & Spence, 2014). However, this relative gap is noteworthy, given how central touch is to everyday social interaction and emotional communication.

For a long time, the skin was viewed primarily as a passive boundary and a tool for the discriminative aspects of touch. However, a crucial distinction has emerged that transforms our understanding of the skin from a mere sensory surface into a complex social organ. While discriminative touch provides us with an objective map of the external world, affective touch encodes the emotional and hedonic domains of our interactions (McGlone et al., 2007, 2014; Morrison et al., 2010; Olausson et al.,

2016). Affective touch has been conceptualised as a category term that captures tactile processing with a hedonic or motivational component, with qualitative and anatomical mechanisms partially distinct from those already identified in discriminative touch (McGlone et al., 2014; Morrison et al., 2010; Morrison, 2016a; Olausson et al., 2010). However, the concept of "affective touch" remains a topic of discussion in the literature. While some authors use the term broadly to refer to the emotional and social dimensions of tactile interaction (e.g., social or pleasant touch; McGlone et al., 2014; Cascio et al., 2019), others reserve it for touch mediated by C-Tactile (CT) afferents, adopting a more neurobiological definition (Björnsdotter et al., 2014; Morrison, 2016a). In the present dissertation, the second definition is adopted, using the term "affective touch" or "CT-targeted touch" to denote tactile stimulation that optimally engages CT pathways and is typically perceived as pleasant and socially meaningful.

This dissertation is born from the premise that the skin is the site of crucial events through which we perceive and engage with the social world. Although research on affective touch has grown in recent decades, several questions remain insufficiently addressed in the literature. Specifically, it is still unclear how individual differences in tactile experiences and attitudes toward touch may influence the perception of affective touch, whether CT-targeted stimulation is associated with distinct neural dynamics compared to other tactile modalities, how affective touch is evaluated and processed from a neurophysiological level when observed in others (i.e., vicarious affective touch), and whether the perception of vicarious affective touch differs in individuals with autism spectrum disorder (ASD), a population often associated with atypical social-affective processing. Through investigation of the link between individual differences, neural dynamics, and vicarious experiences, this work aims to bridge these gaps, offering a more integrated understanding of affective touch.

1.2. Conceptual and Somatosensory Foundations of Touch

1.2.1. Peripheral Touch Encoding

Touch perception begins at the skin level, where a wide variety of specific mechanoreceptors encode different properties of tactile stimulation. These receptors convert mechanical forces into neural signals that are conveyed to the central nervous system through different types of peripheral nerve fibres (Johnson, 2001; Kandel et al., 2021). Mechanoreceptors in the skin have traditionally been classified based on their adaptation characteristics, receptive field size, and functional role. In glabrous skin, there are two main types of low-threshold mechanoreceptors. Type I mechanoreceptors have small receptive fields and provide high spatial resolution, allowing precise detection of fine details. They include slowly adapting type I (Merkel cells) and rapidly adapting type I (Meissner corpuscles). Type II mechanoreceptors

have larger receptive fields and are sensitive to broader, skin-stretch or deep-vibration cues. They include slowly adapting type II (Ruffini endings) and rapidly adapting type II (Pacinian corpuscles) (Johansson & Vallbo, 1979; Johnson, 2001). These mechanoreceptors are low-threshold, as they respond to very light mechanical stimulation of the skin. They are mainly innervated by myelinated A-beta (Aβ) afferent fibres, which conduct signals rapidly (≈ 35 to 75 m/s), have large diameters, enabling the precise encoding of pressure, vibration, texture, and spatial localisation (Kandel et al., 2021; McGlone et al., 2014). Moreover, the somatosensory system is also composed of thinly myelinated A-delta (Aδ) nerve fibres, which have a moderate velocity (≈ 5 to 30 m/s) and are related to the conduction of fast, sharp pain, cold temperatures, and some forms of crude touch (Kandel et al., 2021).

Complementing these fast- and intermediate-conducting fibres, the somatosensory system also includes unmyelinated group C nerve fibres. These fibres conduct signals more slowly (≈ 1 m/s), have small receptive fields, and are typically associated with affective and interoceptive aspects of sensory experiences, including nociception, temperature, and itch (Arcilla & Tadi, 2024; Kandel et al., 2021; McGlone et al., 2014). Among these, a specific subtype of low-threshold mechanoreceptor, the CT afferents, has been found to be present in human hairy skin and is thought to be involved in the encoding of affective qualities of touch (Löken et al., 2009; McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2010; Vallbo et al., 1993).

In summary, the peripheral somatosensory system is organised into specialised afferent classes that work in a complementary manner. While Aβ and Aδ fibres ensure the rapid transmission of discriminative and protective sensory information, C fibres, including CT afferents in particular, are tuned for the emotional characteristics of touch (McGlone et al., 2007, 2014; Morrison et al., 2010; Olausson et al., 2002). This neurobiological foundation supports the subsequent integration of tactile input into the broader socio-emotional frameworks explored in the following sections.

1.2.2. CT Afferents and CT-Targeted Touch

The CT afferent system represents the neurobiological substrate for coding the affective properties of touch. The existence of this slow tactile system and initial investigations into its characteristics were first identified in furry animals approximately 85 years ago, with research continuing over several decades (Douglas & Ritchie, 1957, 1962; Iggo, 1960; Iggo & Kornhuber, 1977; Zotterman, 1939). For some time, it was believed that the C low-threshold mechanosensitive receptors (C-LTMRs, homologous to the CT in animals) were absent in human skin. In fact, many studies failed to document CT afferents, mainly due to experimental constraints, as microneurography (a technique for recording from single nerve human

fibres) was performed on the glabrous skin of the hand (Johansson & Vallbo, 1983). Moreover, some of these studies used the marking technique (a microneurography modification that identifies different types of unmyelinated C fibres based on their post-activation conduction slowing), which is not ideal for identifying CT fibres, due to their minimal axonal slowing (Hallin & Torebjôrk, 1974). Consequently, it was only about 50 years after the first evidence of C-LTMRs in animals that CT afferents were identified in humans. The initial evidence was based on recordings from the face area (Johansson et al., 1988; Nordin, 1990), but soon after, a substantial number of these afferents were discovered in various parts of the body, indicating a broad distribution across the human skin (Edin, 2001; Vallbo et al., 1993, 1999).

In terms of spatial distribution, CT afferents appear to be relatively widespread in areas of hairy skin (e.g., in the forearm), where they seem to be relatively abundant, potentially comparable in prevalence to other low-threshold mechanoreceptors such as Aβ fibres (Löken et al., 2009; Vallbo et al., 1999). However, their exact density remains difficult to quantify, as recording methods like microneurography have some methodological limitations, since these techniques are typically more sensitive to larger nerve fibres, and may underestimate the presence of CT afferents. Despite this, evidence from both human and animal studies (in homologous C-LTMRs) points to the fact that this distribution is not uniform, following a proximal-to-distal gradient of density, in which these fibres become progressively less frequent toward distal body areas, such as the hands and lower legs (Kumazawa & Perl, 1977; Vallbo et al., 1999). In contrast to their prevalence in hairy skin, CT fibres have traditionally been considered absent in glabrous skin (Olausson et al., 2010; Vallbo et al., 1993), which also aligns with findings in other species (Bessou et al., 1971; Georgopoulos, 1976; Kumazawa & Perl, 1977; Liu et al., 2007). However, some findings have raised the possibility that sparse CT afferents may be present in glabrous skin (Nagi & Mahns, 2013; Watkins et al., 2021). Although the distribution of CT fibres in the skin is not well characterised, variations have been observed in the perceived pleasantness of CT-targeted touch (both first-hand and vicarious) across different skin areas of the body (Ackerley et al., 2014; Devine et al., 2020; Essick et al., 1999, 2010; Haggarty et al., 2021a; Walker et al., 2017), with higher pleasantness ratings typically reported for proximal and socially relevant areas, such as the back (i.e., the dorsal region) (Devine et al., 2020; Haggarty et al., 2021a; Walker et al., 2017).

Building on these anatomical distinctions, mechanoafferent CT fibres in humans have a set of characteristic physiological features that distinguish them from other low-threshold mechanoreceptors and support their role in encoding affective aspects of touch. These unmyelinated mechanoreceptors are optimally tuned to gentle and caress-like stroking touch (Olausson et al., 2010; Vallbo et al., 1993), delivered at slow velocities (approximately between 1 and 10 cm/s) and at human skin temperatures (≈

32°C) (Ackerley et al., 2014; Löken et al., 2009; Olausson et al., 2016). This response pattern is often strongly correlated with subjective perception of touch pleasantness (Ackerley et al., 2014; Essick et al., 1999, 2010; Löken et al., 2009). Their firing response follows an inverted U-shaped function of stroking velocity, peaking at approximately 3 cm/s, with reduced activation at both slower (≈ 0.1 cm/s) and faster velocities (≈ 30 cm/s) (Ackerley et al., 2014; Essick et al., 2010). In addition, CT afferents are characterised by relatively low firing rates (≈ 100 impulses/s), higher mechanical thresholds (0.3 to 3 mN) compared to some other tactile afferents, and reduced responsiveness to high-frequency stimulation (Johansson et al., 1988; McGlone et al., 2014; Vallbo et al., 1995, 1999). Furthermore, CT fibres also exhibit after-discharges that persist beyond stimulus offset and pronounced, long-lasting fatigue following repeated stimulation, requiring longer recovery periods, which may suggest a functional specialisation to detect and encode the initial affective salience of touch, rather than repetitive tactile input (Iggo, 1960; Iggo & Kornhuber, 1977; Olausson et al., 2016). Although these characteristics are well established, ongoing research continues to shed more light on the role of CT afferents in affective processing across different contexts, body sites, and individual differences (Ackerley, 2022; McGlone et al., 2014).

Taken together, these findings support the view that CT afferents constitute a specialised peripheral system tuned to the detection and encoding of affective and socially relevant tactile stimuli, complementing the role of fast-conducting Aβ afferents in discriminative touch processing. This distinction highlights a broader organisation of the somatosensory system in which different afferent pathways contribute to the encoding of complementary dimensions of tactile experience. Although the precise mechanisms remain to be completely clarified, converging evidence indicates that CT-targeted input is integrated within broader interoceptive and socio-emotional brain networks. The following section, therefore, explores the peripheral and central pathways underlying discriminative and CT-targeted stimulation in greater detail.

1.2.3. Peripheral-Central Pathways

Despite this growing body of evidence, the spinal mechanisms that relay human CT-related information from the periphery to the forebrain are not well established, largely due to their fine structure and the technical challenges of tracing their central terminals (Marshall & McGlone, 2020). At the spinal level, evidence from animal models indicates that C-LTMR afferents enter the dorsal horn through the dorsal root and synapse with second-order neurons primarily within inner lamina II, and that neurons located in this region respond exclusively to slow stroking and receive input from unmyelinated afferent fibres (see animal studies by Abraira & Ginty, 2013; Larsson & Broman, 2019; Li et al., 2011; Light et

al., 1979; Sugiura, 1996). Neurons in lamina II that are activated by C-LTMR afferents project to lamina I (Lu et al., 2013; Lu & Perl, 2005; Maxwell et al., 2007), where they can connect to wide dynamic range projection neurons that respond to both innocuous and noxious stimuli, including touch and heat (Andrew, 2010; Lu et al., 2013). Such an organisation may support the integration of CT-mediated signals with other emotionally salient and homeostatically relevant sensory inputs. In humans, projections from lamina I are thought to ascend via the spinothalamic tract to the posterior ventromedial region of the thalamus (Craig, 2002). However, a study by Marshall and colleagues (2019), in which they explored the role of the spinothalamic tract in transmitting pleasant touch sensations mediated by CT afferents in patients who underwent anterolateral cordotomy (a procedure that disrupts the spinothalamic tract), showed significant impairments in pain, temperature, and itch perception, but pleasant touch perception remained intact. These findings suggest that CT-related signals are unlikely to be conveyed exclusively by a single labelled line (the spinothalamic pathway) and instead may rely on distributed neural populations and/or multiple pathways in the spinal cord and brain (Marshall et al., 2019; Marshall & McGlone, 2020).

Despite these uncertainties, CT afferent signals, similarly to those conveyed by Aβ afferents, are thought to involve thalamic relay mechanisms before reaching cortical regions (Craig, 2002). However, these pathways appear to diverge at the cortical level. While Aβ afferents predominantly project via the dorsal column-medial lemniscal pathway to primary and secondary somatosensory cortices to support discriminative touch (Kandel et al., 2021; McGlone et al., 2014), CT-targeted input preferentially projects to the posterior insular cortex (McGlone et al., 2014; Olausson et al., 2002). This region has been consistently identified as a primary cortical recipient for CT-targeted touch processing (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2002, 2008a), integrating tactile input into interoceptive and affective frameworks (Gogolla, 2017; Zhang et al., 2024). Evidence from rare clinical cases further supports the functional relevance of CT pathways, as Olausson and colleagues (2002) identified CT afferents in an individual with a rare condition characterised by the absence of Aβ afferents and found that their stimulation elicited activation in the insular cortex. The subsequent recruitment of broader "social brain" networks reflects the higher-order neurofunctional processing of these signals, which is explored in detail in section 1.4.

In sum, Aβ and CT afferents follow partially distinct but complementary processing pathways that reflect their specialised functional roles within the somatosensory system. This neurophysiological foundation, centred on specific thalamic relays and the insular cortex, provides the basis for integrating CT-targeted information into broader socio-cognitive networks. In recent decades, research on CT systems has expanded considerably, contributing to a more comprehensive understanding of their physiological

properties and functional relevance. Beyond these fundamental physiological properties, it is important to consider the broader impact of CT-targeted touch in human life, which is explored in the next section.

1.3. Functional Significance of CT-Targeted Touch

Over the past few decades, the CT system has attracted increasing scientific interest due to its distinct physiological characteristics and relevance to human social behaviour and emotional and social functioning. This specialisation of CT afferents has given rise to hypotheses that aim to explain its broader functional significance, especially regarding its physiological properties and functions in physiological regulation, social bonding, and evolutionary adaptability. These hypotheses are the "social touch" hypothesis, the "interoceptive" hypothesis, and the "thermoregulatory" hypothesis.

1.3.1. Social Touch Hypothesis

The idea that affective touch primarily functions in the domain of social interactions and influences behaviour is the central assumption of the "social touch" hypothesis (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2010). As aforementioned, CT afferents are optimally activated by slow, caress-like stimulation delivered at human-skin-like temperatures, a combination that elicits the highest firing rates and the most pleasant perception (Ackerley et al., 2014; Löken et al., 2009). These tuning properties, together with their slow conduction velocity and diffuse perceptual correlates (Olausson et al., 2002), support the view that CT input is specialised for conveying emotionally salient tactile information, rather than discriminative dimensions. Consistent with this, CT-optimal touch has been shown to be processed by brain areas involved in socio-emotional cognition (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2002, 2008a). Recent findings suggest that CT-optimal touch enhances emotional regulation and motivates affiliative behaviour, reinforcing its social relevance (Walker et al., 2022). Importantly, other tactile modalities, such as deep pressure, can also be experienced as pleasant or calming, indicating that multiple forms of touch may contribute to the broader framework of social touch (Case et al., 2021).

1.3.2. Interoceptive and Regulatory Accounts

Complementing this socio-affective perspective, the "interoception" hypothesis highlights how stimulation of CT afferents influences the perception and regulation of internal bodily processes (Craig, 2002; Migliorini et al., 2013). It redefines interoception based on the type of nerve fibres involved, particularly unmyelinated or thinly myelinated afferents like CTs, which synapse in lamina I of the dorsal

horn and ascend to medial thalamic nuclei, rather than defining interoception solely by whether the sensory signal emerges from within or outside the body (Craig, 2003, 2009). CT afferents, despite innervating the skin, align more closely with interoceptive pathways than with typical exteroceptive touch (Björnsdotter et al., 2010). This afferent pathway is thought to act as a sensory limb of the sympathetic nervous system (Craig, 2003; Olausson et al., 2008b), which may influence autonomic processes such as heart rate, breathing, and stress responses (Seth & Critchley, 2013). According to this perspective, the CT system is a component of a larger interoceptive network that contributes to autonomic regulation and signals the brain about the body's physiological state. However, further empirical evidence is needed to clarify these physiological correlations, particularly for CT-mediated touch in humans.

1.3.3. Thermoregulatory and Evolutionary Accounts

Finally, the "thermoregulatory" hypothesis (Morrison, 2016b) suggests that CT afferents may have evolved from mechanisms originally used to regulate body temperature, particularly in young mammals. This hypothesis proposes that CT fibres may be an adaptation of sensory systems that originally helped in survival through behaviours such as huddling in young animals, rather than being specifically evolved for social communication. These interactions produce patterns of gentle, skin-temperature touch that closely correspond to the optimal stimulus properties of the CT afferents. Given that CT fibres are activated during warm, caress-like contact, this overlap may have enabled them to adopt a new function over evolutionary time, promoting social proximity and emotional bonding (Morrison, 2016b). CT-mediated touch may help buffer stress and promote relaxation by signalling safety and lowering sympathetic arousal (Coan et al., 2006; Morrison, 2016b; Schirmer et al., 2013; Vrontou et al., 2013). This role is consistent with more general models of physiological regulation, in which sensory information helps to preserve bodily balance through anticipatory adaptations connected to social context as well as homeostasis (Schulkin, 2011; Sterling, 2012). Considering this, CT afferents may be part of a sensory system that integrates environmental, temperature, and social inputs into adaptive behavioural and autonomic responses.

Altogether, these hypotheses demonstrate the complex and multifaceted nature of the CT system, suggesting that it supports a variety of affective, interoceptive, and thermoregulatory processes vital to social interaction and human well-being. However, understanding the functional impact of this system requires an investigation into its underlying biological substrate. Following this overview of its evolutionary and social roles, the next section explores how these functions are represented in the human brain through specific neurofunctional and neurophysiological correlates.

1.4. Neural Correlates of Affective Touch

Functional neuroimaging studies, particularly those using functional magnetic resonance imaging (fMRI), have substantially advanced our understanding of the brain regions involved in affective touch processing. While fMRI provides high spatial resolution for identifying the cortical and subcortical areas recruited by affective tactile stimuli, electroencephalography (EEG), with its millisecond-level temporal resolution, offers a complementary perspective by revealing the rapid neural dynamics underlying these processes. Together, these techniques enable the examination of evoked brain activity, shedding light on the timing and evolution of neural responses during affective touch. In the following sections, a more detailed overview of the key findings derived from these two complementary approaches is provided, with a particular focus on the neural mechanisms underlying first-hand perception of affective touch.

1.4.1. Neurofunctional Correlates of Direct Touch

Neuroimaging studies using fMRI and related techniques (e.g., fNIRS) have consistently identified a distributed network of brain areas involved in the processing of direct CT-targeted touch. At the primary cortical level, this input is predominantly processed in the posterior insular cortex, a key region for interoceptive integration, linking tactile signals with internal bodily states (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2002, 2008a). Beyond the insula, CT-targeted touch recruits a broader socio-affective network, often termed the "social brain" (regions commonly associated with social cognition; Brothers, 1990), responsible for the higher-order evaluation of tactile stimuli. These regions include the posterior superior temporal sulcus (pSTS), medial prefrontal cortex (mPFC), amygdala, ventrolateral prefrontal cortex (vlPFC), and orbitofrontal cortex (OFC) (Bennett et al., 2014; Gordon et al., 2013; Kaiser et al., 2016; Lucas et al., 2015; Maria et al., 2022; McGlone et al., 2012; Olausson et al., 2002; Voos et al., 2013). The activation of these regions suggests that CT-targeted stimulation carries motivational and behavioural significance that extends beyond its purely sensory properties, facilitating emotional regulation and social bonding (Perini et al., 2015). This functional organisation is also supported by meta-analytic evidence, which has revealed a relative dissociation between affective and discriminative touch processing, with affective touch strongly associated with the posterior insula, and discriminative touch with the primary somatosensory cortex (Morrison, 2016a). Taken together, these findings suggest that CT-targeted touch recruits brain systems supporting interoceptive awareness, affective evaluation, and socially relevant behaviour.

1.4.2. Neurophysiological Correlates of Direct Touch

In contrast to neurofunctional approaches, EEG studies have focused on characterising the temporal and oscillatory dynamics underlying affective touch processing, although research on neural responses to stroking at different speeds remains relatively limited. Von Mohr et al. (2018) compared a CT-optimal speed touch condition (8 cm/s) with a non-CT-optimal speed (32 cm/s) and a no-touch condition on the forearm. The authors found a suppression of alpha and beta activity (across multiple scalp regions) for the CT-optimal and non-CT-optimal touch speed conditions when compared to the no-touch condition, and a suppression of theta (also across multiple scalp regions) and beta (only in parietal scalp regions) activity for the CT-optimal condition when compared to the non-CT-optimal and no-touch conditions. Other studies using non-CT tactile stimulation (e.g., punctate mechanical stimulation with von Frey filaments) also report suppression of alpha and beta bands during the processing of tactile stimuli in somatosensory areas (Michail et al., 2016; Singh et al., 2014), with alpha showing the strongest response in the parieto-occipital regions, and theta and beta in the frontal and vertex areas (Michail et al., 2016). Together, these findings suggest that oscillatory changes in alpha, beta, and theta bands reflect variation in cortical engagement during tactile processing, although the extent to which these patterns are specific to CT-targeted stimulation remains to be clarified.

Following these findings, behavioural and electrophysiological approaches have been used to further confirm that CT-optimal stimulation results in increased subjective pleasantness ratings as well as differential neural responses. For instance, Schirmer et al. (2022) examined five stroking velocities (0.5, 1, 3, 10, and 20 cm/s) across hairy (i.e., forearm) and glabrous skin (i.e., palm), showing that, in hairy skin, the CT-optimal speed (intermediate velocities) was associated with higher pleasantness ratings (following an inverted U-shaped pattern with velocity) and a larger somatosensory event-related potential (ERP) negativity around 400 ms (sN400) than the faster and slower velocities, suggesting enhanced socio-affective processing of these stimuli. In contrast, this relationship was not observed in glabrous skin, where pleasantness ratings increased linearly and the ERP responses were larger for faster velocities, highlighting functional differences in affective touch processing across skin types.

Finally, Varlamov et al. (2022) compared neural responses to slow (5 cm/s) and fast (30 cm/s) stroking conditions on the forearm, finding ERP components around the time interval 400-1800 ms over the lateral frontal and central areas, with a higher amplitude for the fast condition. This pattern was interpreted as reflecting the predominant contribution of fast-conducting Aβ afferents to early cortical responses. In contrast, slow stroking elicited a P2100-N2300 complex, presumably related to the termination of the tactile stimulation, and an ultra-late positive potential (LPP) that has been proposed to

reflect the delayed processing of CT afferent input. In sum, these electrophysiological findings highlight how the temporal dynamics of cortical processing differ between the two tactile systems, with CT-related activity appearing at later stages of neural response.

Overall, the electrophysiological evidence suggests that CT-targeted stimulation is associated with distinct temporal dynamics and oscillatory patterns, including delayed cortical responses and modulation of alpha, beta, and theta activity. Rather than reflecting entirely separate systems, these findings suggest differences in the timing and functional engagement of neural processes underlying affective and discriminative aspects of touch. However, further research is needed to clarify the degree to which these neural processes are specific to CT-targeted input and to individual differences.

1.5. Vicarious Affective Touch

In addition to direct tactile experiences, studying responses to vicarious processing of affective touch offers important insights into how the brain represents the emotional significance of others' tactile experiences. This perspective is particularly relevant given the inherently social nature of touch, as it allows the investigation of socio-affective functions even in the absence of physical contact. Importantly, this approach has been investigated using both neurofunctional and neurophysiological methods, which provide complementary insights into the spatial and temporal dynamics of vicarious touch processing.

Functional neuroimaging studies have suggested that the observation of affective touch recruits neural systems that partially overlap with those involved in direct tactile experience, supporting the existence of mirror-like mechanisms (Bolognini et al., 2014; Ebisch et al., 2011; Keysers et al., 2004, 2010; Lee Masson et al., 2018); Morrison et al., 2011; Schaefer et al., 2005, 2009, 2012). Similarly, observing CT-targeted touch has been found to activate the aforementioned socio-affective network even in the absence of the direct touch. For instance, Morrison et al. (2011) found that observing someone receiving a CT-targeted touch elicits activation of the posterior insular cortex, particularly when performed at CT-optimal speeds. This is further supported by Gordon et al. (2013), who demonstrated that observing CT-targeted touch elicited increased activation of the socio-affective network. Their findings revealed increased functional connectivity between medial prefrontal areas and limbic structures, reinforcing the role of the CT system in higher-order socio-emotional processing, whether experienced first-hand or vicariously.

Complementing these findings, there has been a small body of EEG studies that have started to characterise the temporal dynamics underlying the observation of affective touch. The literature on vicarious affective touch remains scarce, yet emerging findings consistently point to the engagement of

sensorimotor and affective systems during the observation of social touch. Peled-Avron et al. (2016) demonstrated that viewing human touch, compared with non-social or no-touch scenes, induced greater mu-suppression (oscillations in the alpha band [≈10 Hz] observed at central sites and related to sensorimotor activation). This modulation appears to be further influenced by the participants' empathy levels, suggesting that individual socio-affective traits shape neural resonance to observed touch. Alpha band activity was observed across different sensory areas of the brain (although it is prominent in the visual cortex), and its desynchronisation was interpreted as reflecting the prioritisation of relevant sensory input (Van Diepen et al., 2019). Furthermore, Schirmer & McGlone (2019) found that observing drawings depicting affective touch, when compared with no-touch interactions, produced increased power in both alpha and beta bands, as well as enhanced LPP over centro-parietal areas, and this difference was more pronounced when touch was processed explicitly rather than implicitly. This ERP component is reported to be affected by attention allocation and emotion processing (Nowparast Rostami et al., 2016; Pollux, 2016), is commonly observed over centro-parietal areas, and is modulated by emotionally charged content (Liu et al., 2012; Zhu et al., 2015). Taken together, these findings suggest that the simple observation of affective touch engages early sensorimotor and later evaluative neural processes, underscoring the emotional and social salience of tactile interactions even in the absence of physical contact.

Beyond the frequencies previously discussed, other oscillatory bands can offer valuable insights into affective touch. The beta rhythm is particularly modulated over the motor and somatosensory cortex, with its desynchronisation during movement followed by a post-movement rebound, a pattern that is interpreted as a correlate of inhibition of return to an idling state after the termination of a motor program (Nam et al., 2011; Pfurtscheller et al., 2006; Stavrinou et al., 2007). Oscillations in the beta range are modulated during actual and imagined movement and during action observation (Brunsdon et al., 2019; Galdo-Alvarez et al., 2016). Additionally, beta suppression has been linked to somatosensory and motor processes, particularly in response to affective and social stimuli. This phenomenon is thought to reflect the brain's engagement with emotionally salient information, involving both sensory and attentional components (Charidza & Gillmeister, 2022). Finally, theta band activity is prominent over mid-frontal locations, its power increases during tasks that require greater attentional resources or that involve the initiation of cognitive control processes (Cavanagh & Frank, 2014) and is sensitive to the emotional content of the stimuli (Pidal-Miranda et al., 2019; Sammler et al., 2007). In addition, it has been observed that theta plays a role in attentional processes related to somatosensory input (Shen et al., 2019; Zhang et al., 2019). Therefore, given their role in sensorimotor and emotional processing, integrating the

analysis of beta and theta bands alongside alpha and LPP may be relevant for a comprehensive understanding of affective touch.

Overall, these findings highlight that CT-targeted touch recruits a distributed network of brain regions and dynamic neural processes associated with sensorimotor, affective, and socio-cognitive functioning. When combining evidence from both functional neuroimaging and electrophysiological approaches, it becomes clear that affective touch is not only represented at multiple levels of the nervous system but also involves a complex interplay between perception and emotional processes. However, these neural pathways are not universal, since their disruption might lead to changes in perception of the socio-environmental context. This leads to the following section, which examines how affective touch processing evolves across development and how it is characterised in populations where socio-affective and sensory integration are atypical, with a particular focus on ASD.

1.6. Affective Touch Across Development

Disruptions in the perception or integration of affective touch have the potential to affect interpersonal functioning, emotional well-being, and adaptive behaviour. CT-optimal touch has been shown to produce pleasant sensations (Löken et al., 2009), as well as engage brain regions associated with social cognition, emotional regulation, and homeostatic balance (Craig, 2002, 2009; Gordon et al., 2013; Voos et al., 2013). These findings are especially relevant in clinical settings, as they highlight how affectionate touch can promote emotional relief and help regulate stress responses. For instance, in hospital and long-term care environments, touch-based interventions have been shown to reduce anxiety, stabilise physiological arousal, and enhance perceptions of social support, particularly in patients experiencing isolation or reduced mobility (Garrett & Riou, 2021).

In addition, affective touch contributes to a wide range of psychosocial and emotional processes, reducing feelings of loneliness, alleviating anxiety, and increasing social connectedness (von Mohr et al., 2021), and it also plays a role in regulating stress (Kidd et al., 2023). The clinical relevance is particularly evident in fragile populations or those at risk of social isolation, such as older individuals, those hospitalised for extended periods, and people with neurocognitive decline. Importantly, opportunities for physical contact tends to decrease in older age, which can exacerbate feelings of isolation or loneliness, highlighting the importance of touch throughout life (Field, 2001). Affective touch also appears to influence intimacy and emotional communication, helping in the nonverbal communication of affection, trust, and connection (Hertenstein et al., 2006). Gentle and dynamic touch has been found to stimulate reward circuits and create a sense of security, and romantic and long-term couples frequently rely on

tactile cues to regulate emotions and reinforce bonds (Coan et al., 2006; Nelson & Geher, 2007). These interactions are usually felt as deeply rewarding, partly due to the involvement of CT afferents and neurochemicals such as oxytocin, which foster bonding and reduce stress (Bales & Carter, 2003; Gulledge et al., 2007; Young, 2002). Affective touch also plays a role in clinical contexts where social connectedness and bodily awareness are affected; for instance, individuals with anorexia nervosa show reduced pleasantness of CT-optimal touch and atypical insular activation, suggesting disturbances in interoceptive-affective processing and in the ability to derive comfort from social contact (Crucianelli et al., 2016). Further research indicates that this tactile anhedonia may be driven by altered top-down anticipatory beliefs about touch, as both acute and recovered patients rate CT-optimal and non-optimal touch as less pleasant than healthy controls (Crucianelli et al., 2021).

Furthermore, studies have shown that the CT system can also mediate some forms of pain. Recent studies suggest that CT-optimal touch can modulate nociception and reduce the perception of both physical and social pain (Habig et al., 2017; Liljencrantz et al., 2017; Shaikh et al., 2015; von Mohr et al., 2017, 2021). Recent electrophysiological findings further suggest that CT-targeted stimulation may modulate somatosensory processing beyond subjective perception, modulating later cortical responses related to the attentional and cognitive components of the tactile sensation (Ribeiro-Carreira et al., 2025). This modulatory effect may contribute to adaptive regulation of pain experiences, potentially alleviating physical and social distress. In line with this, recent research also suggests that CT-targeted stimulation can attenuate central pain sensitisation processes, which may be connected to a decrease in the attention given to nociceptive stimulation (da-Silva et al., 2025). Given this analgesic role, conditions characterised by altered pain perception, such as chronic pain, may involve dysregulation of CT-mediated processes (Boehme et al., 2020; Evdokimov et al., 2019). Consistent with this, studies in chronic pain populations have reported reduced pleasantness ratings to CT-optimal touch and altered neural responses in affective and interoceptive regions such as the insula, suggesting impairments in both the sensory and evaluative components of affective touch processing (Boehme et al., 2020; Gossrau et al., 2021; Nees et al., 2019).

Importantly, cultural differences also shape these clinical outcomes throughout touch practices and their meanings, with some societies placing higher value on tactile interactions than others, demonstrating that these effects are embedded within social and contextual frameworks that vary across societies (Field, 2001; Jourard, 1966; Suvilehto et al., 2019; Watson, 1970). Moreover, the frequency and type of touch exchanged are also influenced by other factors such as gender (Dibiase & Gunnoe, 2004). These findings highlight the importance of personalised touch-based interventions.

Finally, affective touch is considered crucial in early development and attachment formation (Stratton, 1983). Alterations in CT processing have been observed in neurodevelopmental conditions characterised by atypical sensory-perceptual processing such as ASD, where atypical responses to social touch are frequently observed (Baker et al., 2008; Brandwein et al., 2015; Marco et al., 2011), which show up as reduced pleasantness ratings, avoidance or defensive reactions to social interaction, and hypo- or hyper-sensitivity (Baranek et al., 2006; Cascio et al., 2016; Foss-Feig et al., 2012; Hyman et al., 2020; Kaiser et al., 2016; O. Miguel et al., 2017). The following sections will explore these effects in greater detail, particularly in the context of neurodevelopment and ASD.

1.6.1. Development and Attachment

The fundamental importance of touch in early development has been extensively demonstrated across both animal and human research, highlighting its significance for attachment formation, emotional regulation, and neurobiological development. Touch does not simply have a sensory function but plays a central part in the development of socio-emotional and physiological systems from childhood onwards. In this line, touch represents a fundamental sensory modality through which infants' interactions with the environment and caregivers are established, contributing to the development of core regulatory and relational processes.

Classic studies in non-human primates have provided significant evidence for the role of touch in attachment and emotional development. For instance, Harlow (1958) demonstrated that infant rhesus monkeys (sharing approximately 93% of their genes with humans) prefer tactile comfort from an artificial soft surrogate mother rather than nourishment from a wire one, highlighting the importance and primacy of physical comfort in emotional security. Deprivation of soft touch in primates led to altered behaviours and reproductive difficulties, reinforcing the evidence that touch is essential to the development of attachment (Harlow, 1958; Hertenstein et al., 2006; Jensen, 1965; Mendoza et al., 1978; Mitchell & Tokunaga, 1976). These findings are further supported by naturalistic studies of mammalian grooming behaviours, which also underscore the social significance of touch, appearing to serve as a fundamental form of social bonding and affiliative communication (de Waal, 2009; Dunbar, 1998, 2010).

At a neurobiological level, tactile stimulation has been associated with developmental alterations through epigenetic mechanisms. Rodent studies have shown that pups receiving high levels of maternal nurturing develop a more resilient stress response and become calmer adults, whereas the opposite leads to increased anxious-like behaviours. These changes are partly due to epigenetic modifications in stress-related genes, in which the amount of care a rat mother provides her offspring alters the DNA chemistry

in certain genes related to the stress response (Weaver et al., 2004). Extending these findings, Curley et al. (2008) demonstrated that poor maternal care in rats leads to long-lasting behavioural alterations in the offspring, including reduced exploratory behaviour and increased neophobia (i.e., the fear of anything unfamiliar). These effects are likewise mediated by epigenetic modifications rather than genetic mutations, specifically changes in DNA methylation patterns in genes regulating stress responses, such as the glucocorticoid receptor gene in the hippocampus. These findings highlight how early tactile experiences can induce long-lasting changes in gene expression, thereby shaping emotional regulation and behavioural outcomes across the lifespan.

Converging evidence from human studies supports these findings, showing that early tactile interactions and nurturing caregiving play a crucial role in shaping emotional, physiological, and social development. Lack of tactile input, especially social and affective touch, has been linked to significant emotional and developmental challenges, whereas other sensory modalities such as vision or hearing can be absent without severely impairing psychological development (Gallace & Spence, 2014). Early tactile experiences, such as skin-to-skin contact between newborns and caregivers, are crucial for fostering secure attachment, emotional health, and healthy brain development, as the structure and function of the brain are shaped in part by this type of nurturing connection (Duhn, 2010; Hertenstein et al., 2006; Nelson et al., 2014). Neuroimaging and behavioural studies suggest that the brain systems underlying affective touch are functional from early life. For instance, seven-month-old infants show increased somatosensory cortical activation in response to affective and discriminative touch, although socio-emotional brain regions such as the pSTS are not yet recruited at this age (O. Miguel et al., 2019). However, follow-up studies demonstrate that by 12 months, the pSTS becomes more sensitive to affective touch, and infants who exhibit fewer aversive responses to tactile stimuli also exhibit increased pSTS activity, suggesting early connections between individual behaviour patterns and socio-emotional touch processing (O. Miguel et al., 2020). Furthermore, maternal sensitivity also plays a role in modulating infants' neural responses, with lower levels of maternal sensitivity at 7 months associated with higher somatosensory responses to affective touch and higher temporal cortical responses to discriminative touch at 12 months, indicating that early caregiving can shape the maturation of neural touch processing (Mateus et al., 2021). These findings demonstrate that affective touch has significant implications for physiological and emotional regulation, but also for the development of socio-cognitive neural networks. Significantly, the role of tactile social contact extends beyond infancy, promoting well-being and social connection across the lifespan (Field, 2001). Through neurobiological mechanisms involving the activation of the hypothalamic-pituitary axis and the release of neuropeptides such as oxytocin, social

touch contributes to stress reduction, emotional bonding, and the maintenance of close interpersonal relationships in adulthood (Gulledge et al., 2007; Holt-Lunstad et al., 2008). Oxytocin has been shown to mediate the rewarding and affiliative effects of touch by modulating limbic and autonomic activity, reinforcing trust and social cohesion (McGlone et al., 2014; Walker et al., 2017).

In neonatal care, skin-to-skin contact is considered a standard clinical practice and is recommended by international guidelines (Brimdyr et al., 2023; World Health Organization, 2022), due to its well-established benefits for physiological regulation and healthy development, showing improvements in physiological stability, stress regulation, and clinical outcomes (Almgren, 2018; Lord et al., 2023; Nitzan et al., 2025; Teles et al., 2025). The "kangaroo care" method, which entails placing the newborn in direct contact with a caregiver's chest, typically for at least an hour and repeated multiple times a day, has been associated with improved physiological regulation, including stabilisation of heart rate, breathing, and sleep patterns (Boundy et al., 2016; Nitzan et al., 2025; Rodgers, 2013). Studies on premature infants have shown that early physical touch in fragile newborns not only stabilises vital signs but also promotes weight gain, improves sleep patterns, and accelerates brain development (Bell & Tepe, 2011; Du et al., 2024; Lazarus et al., 2024; Sivanandan & Sankar, 2023; WHO Immediate KMC Study Group et al., 2021).

Moreover, evidence from conditions of early deprivation also highlights the importance of tactile stimulation. A longitudinal study with children raised in institutional environments with minimal emotional and physical nurturance revealed long-term neurodevelopmental alterations, including reduced grey matter volume (Nelson et al., 2014). Although such environments involve multiple forms of deprivation, the lack of opportunities for tactile and caregiver interaction is considered an important contributing factor, given the central role of touch in early development.

Although these findings do not specifically isolate CT-targeted stimulation, evidence suggests that affective touch may play a particularly important role in regulating physiological and social processes in early life. Studies in infants have shown that affective touch can stabilise the child, increasing respiratory sinus arrhythmia and heart rate variability, which are indices of parasympathetic regulation linked to emotional regulation and social development (Fairhurst et al., 2014; Feldman et al., 2010). In line with this, CT-targeted stimulation is thought to modulate neurophysiological responses associated with autonomic regulation and affective processing, which further supports its functional relevance.

Taken together, these results highlight how early affective tactile experiences contribute to the shaping of emotional, physiological, and social development throughout the lifespan. Through its interplay with neurobiological, epigenetic, and physiological systems, touch is critical for the development of

systems underlying emotion regulation, stress, and social behaviours. Considering the proposed functions of CT afferents in affective touch, any disruptions in these processes may have significant implications for neurodevelopmental conditions that exhibit atypical sensory and social experiences, such as ASD. In line with this, examining how affective touch is perceived and processed in ASD is particularly relevant for understanding the underlying mechanisms of these developmental differences. The following section will explore these alterations in greater detail.

1.6.2. Affective Touch and Atypical Development: The Case of Autism Spectrum Disorder

ASD is a neurodevelopmental condition characterised by persistent impairments in social communication and interaction, alongside restricted and repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2022). In addition, individuals with ASD often present atypical sensory-perceptual processing (Baranek et al., 2006), particularly in response to tactile, auditory, and visual stimuli (Baker et al., 2008; Brandwein et al., 2015; Marco et al., 2011). Among these, tactile processing impairments are particularly prevalent, including hypo- and hyper-responsiveness, avoidance or defensive reactions to touch, and diminished pleasantness ratings (Baranek et al., 2006; Cascio et al., 2016; Foss-Feig et al., 2012; Hyman et al., 2020; Kaiser et al., 2016; O. Miguel et al., 2017). Additional atypical patterns include unusual responses to textures, difficulties in adjusting to prior sensory experiences, and an intense interest in the sensory features of objects (Tomchek & Dunn, 2007). These sensory impairments in ASD can affect how individuals react to touch and other sensory cues, which can be overwhelming or uncomfortable (American Psychiatric Association, 2022; Tomchek et al., 2018). They also significantly shape how individuals experience and interpret social touch, often resulting in discomfort or avoidance behaviours that interfere with communication and social bonding (Foss-Feig et al., 2012; Reynolds et al., 2011; Tomchek et al., 2018).

Given the growing knowledge about the socio-affective role of touch, particularly that mediated by CT afferents, studies have started to investigate how individuals with ASD interpret this type of information. Evidence suggests that they exhibit altered responses to CT-targeted touch, often revealed through reduced discrimination or lower pleasantness ratings and more defensive or avoidance reactions to tactile stimuli compared to neurotypical individuals (Baranek et al., 2006; Cascio et al., 2016; Foss-Feig et al., 2012; Kaiser et al., 2016). Moreover, these individuals tend to exhibit more defensive responses, particularly in areas of the body with a high density of CT afferents (e.g., forearm), compared to areas with lower CT innervation (e.g., palm) (Cascio et al., 2016). Additionally, compared to neurotypical individuals, people with ASD rate this type of touch as less pleasant (Ackerley et al., 2014; Essick et al.,

1999, 2010; Löken et al., 2009). These patterns may suggest that the CT system activation may be perceived as less socially meaningful or less effective in providing socially rewarding experiences in ASD (Jackson et al., 2022). However, this interpretation remains debated and should be considered alongside alternative possible explanations. Other models focus on broader alterations in perceptual sensitivity and responsivity in ASD, suggesting that atypical responses to affective touch may arise from differences in low-level sensory responsivity (e.g., hyper- or hypo-reactivity), which in turn affect affective and social judgments of touch (Baranek et al., 2006; Cascio et al., 2016; Foss-Feig et al., 2012; Hyman et al., 2020; Kaiser et al., 2016; O. Miguel et al., 2017). According to this perspective, the differences in affective touch processing may not be specific to the CT system per se but rather reflect more general alterations in sensory responsivity and salience attribution. Regarding the vicarious processing of affective touch, Haggarty et al. (2021b) examined how neurotypical adults and children evaluate videos depicting an actor being touched at different body sites and at different speeds. The authors found that neurotypical adults with higher autistic traits presented more negative ratings for touch, particularly when delivered to the palm. Contrary to expectations, children's touch ratings were unaffected by autism diagnosis, despite parents reporting greater somatosensory sensitivity. The authors suggested that vicarious tactile perception in children relies primarily on bottom-up affective resonance (automatic sensory mapping), and that the modulation of the same touch by autistic traits observed in adults likely depends on top-down cognitive evaluation of the social context, a process that is not fully developed or engaged in this specific task in childhood. These results highlight that even subclinical autistic traits may modulate the perception of affective touch.

Regarding the neural processing of CT-targeted touch, individuals with ASD show atypical patterns that reflect disruptions in both the socio-affective and discriminative tactile systems. These alterations are thought to reflect underlying differences in the integration of sensory and emotional information. In line with this, several functional neuroimaging studies have investigated how individuals with ASD respond to tactile stimulation in body areas with different densities of CT afferents. Kaiser et al. (2016) found that children and adolescents with ASD, compared to neurotypical individuals, showed reduced activation across the entire socio-affective network in response to CT-targeted touch to the forearm compared to non-CT-targeted touch in the palm. In contrast, these individuals showed increased activation in primary somatosensory areas for the non-CT-targeted, suggesting a neural shift where affective touch is processed through a more discriminative lens rather than an affective one. In addition, these differences were negatively correlated with autism symptom severity, reinforcing the link between atypical cortical recruitment and social impairments. Specifically, activity in the STS, a central region for social perception,

exhibits contrasting patterns: while in neurotypicals it was positively associated with the perception of affective touch, it shows an inverse correlation with autistic traits (Perini et al., 2021; Voos et al., 2013).

EEG and psychophysical findings have also suggested similar patterns, supporting the idea that ASD is characterised by disruptions in both early sensory encoding and higher-order affective evaluation of touch (Blakemore et al., 2006; Cascio et al., 2008; Coskun et al., 2009; Haggarty et al., 2020). For instance, studies analysing tactile ERPs in ASD have reported alterations in early components such as reduced or delayed responses to gentle tactile stimulation (Blakemore et al., 2006; Cascio et al., 2008), suggesting atypical initial cortical processing of somatosensory input. Additionally, individuals with ASD tend to show diminished mu and beta suppression during the perception or observation of touch, reflecting reduced sensorimotor resonance and a decrease in the integration of the social-affective significance of tactile events (Coskun et al., 2009; Haggarty et al., 2020). Taken together, these findings suggest that individuals with ASD show atypical processing of pleasant, CT-targeted touch, resulting in a diminished integration of the emotional and social significance of tactile stimuli.

Overall, individuals with ASD respond to tactile stimulation in very diverse and unique ways, particularly when it comes to the social and emotional aspects of touch. These behavioural and neurological differences may result from a complex interaction between altered socio-affective processing and sensory responsivity, and differences in neural integration across brain networks. Instead of reflecting a single deficit, current evidence suggests a multidimensional difference in the way tactile information is perceived, evaluated, and integrated within social contexts. Notably, despite the growing body of research on direct affective touch in individuals with ASD, there is still a lack of studies examining the perception and neural processing of vicarious affective touch in this population. Understanding these processes may provide important insights for the development of targeted interventions that use affective touch to promote emotional and social functioning in individuals with ASD. In this context, exploring the perceptual mechanisms of affective touch appears to be important for clarifying how these processes differ between neurotypical and autistic populations.

1.7. Theoretical Framework of the Dissertation

The present dissertation is based on a neurocognitive framework of affective touch that integrates models of interoception with predictive processing accounts to explain how affective touch is perceived and interpreted. From an interoceptive perspective, affective touch is defined as a socio-interoceptive signal, whose role is to contribute to the representation of internal bodily states supporting emotional and social significance and regulation. However, rather than being passively received, these body signals are

actively interpreted through predictive mechanisms. According to predictive processing accounts (Friston, 2010; Kilner et al., 2007), the brain is constantly generating and updating predictions about sensory input based on past experiences, contextual information, and social expectations. Thus, the perception of affective touch is the result of an interaction between bottom-up sensory input and top-down contextual and social inference mechanisms. More specifically, bottom-up processes are driven by peripheral afferent systems, including CT fibres, that convey affective dimensions of touch to central brain regions involved in interoception and emotion. In parallel, top-down processes involve individual variations in touch experiences, attitudes towards touch, prior expectations, and socio-affective context interpretations. The integration of these processes allows tactile input to be transformed into socially meaningful and emotionally relevant experiences. In addition, the present framework is complemented by embodied simulation accounts (Gallese, 2005; Morrison et al., 2010), which propose that the perception of others' tactile experiences involves the activation of shared sensorimotor and affective representations. This perspective is particularly relevant for understanding vicarious affective touch, as it provides a mechanism through which observed touch can be internally simulated and interpreted.

This framework provides a useful perspective for interpreting the empirical studies included in this dissertation. The studies address complementary aspects of affective touch that can be discussed in relation to these theoretical accounts. Across the four studies, different dimensions of affective touch are examined, including individual differences in experiences and attitudes towards touch, neural responses associated with direct tactile stimulation, and the perception of affective touch in vicarious contexts (in neurotypical individuals and in individuals with ASD). Taken together, these studies shed light on how sensory input, individual variability, and contextual factors interact in the perception of affective touch.

1.8. The Present Dissertation

1.8.1. Rationale and Objectives

The research presented in this dissertation was designed to address important gaps in the current literature on affective touch, particularly concerning the CT system, which, despite extensive research in the context of perceptual and emotional experiences, remains only partially understood. In particular, limited attention has been given to how individual differences in tactile experiences and attitudes toward touch shape the perception of affective touch, how CT-targeted stimulation is reflected in cortical dynamics during direct tactile stimulation, and how affective touch is processed in the context of the vicarious perception of social interactions. Furthermore, relatively few studies have addressed these issues using approaches that integrate behavioural, psychometric, and neurophysiological measures, or

have explored these mechanisms in clinical populations such as individuals with ASD. Focusing on ASD allowed us to examine a population often characterised by atypical sensory processing and social interaction patterns, providing a unique opportunity to investigate how alterations in tactile sensory processing and socio-affective functioning may influence the perception of CT-related stimuli.

To address these limitations, the present dissertation aims to provide a comprehensive exploration of affective touch by combining different methodological approaches, including psychometric, behavioural, and neurophysiological methods. The studies reported here are intended to contribute to the advancement of current understanding of affective touch perception and processing, while also examining variability across contexts (direct vs vicarious touch) and populations (neurotypical vs autistic individuals), with a specific focus on the role of the CT system in shaping these processes. This approach enables a more comprehensive understanding and characterisation of affective touch by making a link between sensory mechanisms and higher-order socio-cognitive processes, thereby overcoming some limitations of the current literature.

Therefore, the main objectives underlying this thesis were: 1) to develop and validate a psychometric self-report instrument to assess individual differences in experiences and attitudes toward touch; 2) to explore how different types of tactile stimulation (affective touch vs discriminative stimulation) are perceived and processed at both behavioural and neural levels in neurotypical adults; 3) to investigate the subjective perception and neurophysiological correlates of vicarious affective touch in neurotypical adults; and 4) to investigate the subjective perception of vicarious affective touch in adolescents and young adults with ASD, in order to understand potential differences in the processing of affective touch. These objectives are addressed through four complementary studies.

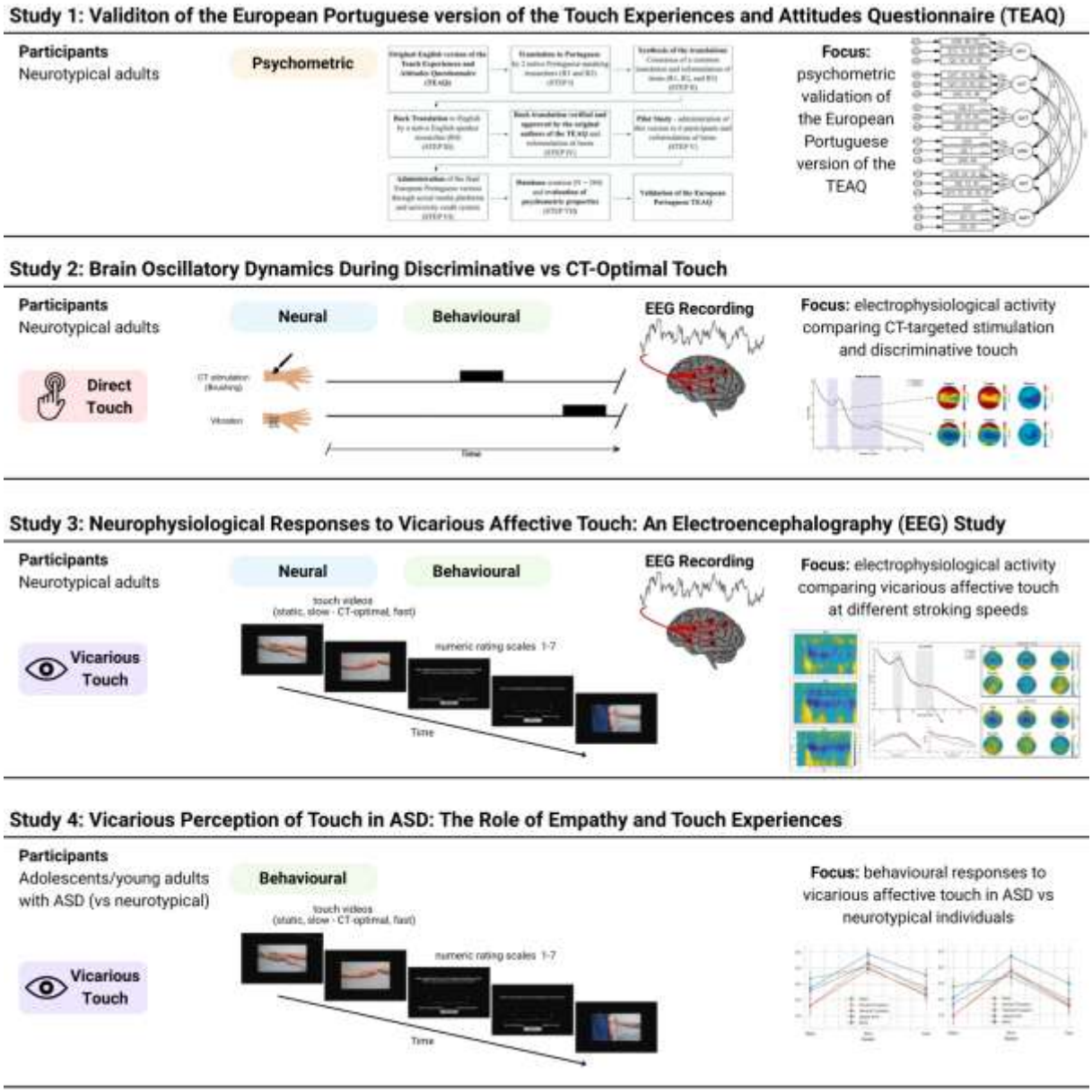
1.8.2. Thesis Structure

This dissertation is organised into six chapters, following a logical progression that moves from theoretical grounding and tool validation to experimental investigation in neurotypical and clinical populations. Chapter 1 (the present chapter) introduces the theoretical background, outlines the main research questions, and defines the objectives of the thesis, establishing the need for an integrative approach to understand individual and clinical variability. Since individual experiences and attitudes act as a filter for sensory experiences and it was essential to standardise this measurement, Chapter 2 presents the psychometric validation of a self-report tool specifically designed to assess individual differences in experiences and attitudes toward affective touch, providing the necessary framework for the subsequent experimental studies. Based on this, Chapter 3 focuses on the behavioural and neural

level (through EEG) to explore how CT-targeted touch is processed during direct tactile stimulation in neurotypical adults, that distinguish affective from discriminative touch at the sensory level. While Chapter 3 explores direct touch, social interaction often involves observing others. Thus, Chapter 4 extends this approach to vicarious contexts, examining behavioural and neurophysiological correlates (also using EEG) of vicarious affective touch in neurotypical individuals to explore how the brain represents the touch of others. To understand the boundaries of these mechanisms in atypical development, Chapter 5 explores vicarious affective touch perception in adolescents and young adults with ASD, comparing their responses to the neurotypical patterns identified in previous chapters to better understand how affective touch perception may differ in this clinical population. Finally, Chapter 6 concludes the dissertation with an integrative general discussion of the main findings, their implications and limitations, and directions for future research. The experimental design of the four studies described above are schematically presented in Figure 1.

Figure 1

Overview of the Experimental Designs and Conceptual Structure of the Dissertation



1.8.3. EEG Methodology

EEG was used in two experimental studies (Chapters 3 and 4) to investigate the temporal dynamics of neural responses associated with CT stimulation and observation. This non-invasive neurophysiological method was particularly suitable for this purpose due to its high temporal resolution, allowing the investigation of the rapid neural dynamics underlying both CT-targeted touch stimulation and vicarious affective touch. More specifically, this technique records voltage fluctuations at the scalp that presumably reflect post-synaptic potentials from cortical neurons, making it a useful technique for examining dynamic and time-locked brain responses to sensory inputs, with millisecond-level resolution (Amzica & Lopes da

Silva, 2017; Niedermeyer & Lopes da Silva, 2005). One widely used EEG method is the ERPs, which are the average of EEG responses that are time-locked to stimulus presentation, providing information on both early and late phases of sensory and cognitive processing (Luck, 2014).

Beyond ERPs, time-frequency technique allows us to assess oscillatory brain dynamics that are not strictly phase-locked to stimulus onset. Since EEG signals often fluctuate depending on mental states and task-related demands, thus making them non-stationary, time-frequency analysis addresses this by decomposing the EEG signal into its constituent time- and frequency-specific elements. This approach enables the examination of transient changes in oscillatory power and phase as they unfold over time, as well as how the signal evolves, and across different frequency bands (Cohen, 2014; Gable et al., 2022). The strength of a brain oscillation is thought to reflect the level of synchrony among excitatory or inhibitory postsynaptic potentials. When power increases, it suggests that local neurons are firing more synchronously, and when power decreases, it indicates a more desynchronised pattern of activity (Gable et al., 2022). This allows for the identification of both event-related desynchronisation and synchronisation, which may reflect engagement or disengagement of specific neural populations (Pfurtscheller & Aranibar, 1977).

Complementing this, power spectral density (PSD) quantifies the distribution of signal power within different frequency bands, providing a more stable estimate of overall cortical excitability and network synchronisation (Teplan, 2002). Unlike time-frequency analyses, which focus on how oscillations change over time in response to events, PSD provides a more stable measure of the brain's baseline or task-related activity within specific frequency ranges. By averaging power across longer time windows, PSD can reveal dominant oscillatory patterns that characterise general states such as arousal, relaxation, or attention (Teplan, 2002). In this way, PSD not only complements event-related and time-frequency analyses but also contributes to a broader understanding of how specific neural oscillations support affective processing and cognitive engagement during social and sensory experiences.

In the context of this dissertation, specific attention is given to oscillatory activity in the theta (3-6 Hz), alpha/mu (9-12 Hz), and beta (16-22 Hz) bands, which are associated with attentional, sensorimotor, and socio-affective processing. Although mu rhythms fall within the alpha frequency range and are often used interchangeably in the literature, they are considered distinct due to their topography and functional specificity. While posterior alpha activity is associated with visual attention and arousal, mu rhythms are typically observed over central regions and linked to motor and somatosensory processes (Gable et al., 2022). In the context of affective touch, desynchronisation in alpha/mu and beta power is particularly relevant, as it is thought to reflect increased cortical engagement and sensorimotor processing

in response to salient tactile stimuli. This interpretation is supported by the "information via desynchronisation" hypothesis, which suggests that power reductions in these bands are associated with enhanced neural processing efficiency and more complex or intensively engaged processing (Griffiths et al., 2019; Hanslmayr et al., 2012). Additionally, increased mid-frontal theta activity has been associated with cognitive control and attentional processes (Cavanagh & Frank, 2014), the processing of emotionally salient stimuli (Pidal-Miranda et al., 2019; Sammler et al., 2007), and attentional mechanisms involved in processing somatosensory information (Shen et al., 2019; Zhang et al., 2019). Taken together, these oscillatory markers provide a framework for examining how CT-targeted touch is processed at the neural level in this dissertation, allowing the investigation of both sensory-driven (bottom-up) and cognitively modulated (top-down) aspects of affective tactile stimulation.

Beyond oscillatory analyses, EEG microstates offer a complementary approach to characterising large-scale brain dynamics. Microstates are brief periods of quasi-stability in scalp topographies lasting 80 to 120 milliseconds (Wackermann et al., 1993). They are often described as the "atoms of thought", representing brief, synchronised activations of large-scale neural networks (Koenig et al., 1999; Lehmann et al., 1987). Microstate analysis segments the EEG signal into a sequence of scalp configurations, each thought to represent a specific mode of information processing. Research has consistently identified four prototypical microstate classes, labelled A to D, each associated with specific functional significance: A (temporal regions), related to auditory processing and levels of arousal; B (occipital regions), linked to visual processing; C (anterior cingulate cortex and inferior frontal regions), related to self-referential and interoceptive processing; and D (fronto-parietal regions), linked to attention-related processing and executive functioning (Schiller et al., 2023). This method offers a global view of neural dynamics and has recently been further explored for its potential to characterise sensory and cognitive states with high temporal precision (Khanna et al., 2015; Michel & Koenig, 2018). In the present dissertation, microstate analysis is used to complement spectral findings by providing a global characterisation of how affective touch modulates large-scale brain dynamics over time.

By allowing the measurement of time-locked responses, oscillatory and topographical changes across different frequency bands, EEG provides a unique window into how affective tactile stimuli are processed in the human brain. In the context of the present dissertation, this approach is particularly valuable for capturing the rapid neural dynamics associated with both direct and vicarious affective touch. Importantly, the combination of event-related, time-frequency, and microstate analyses enables a comprehensive characterisation of the temporal organisation and functional relevance of neural activity underlying CT-targeted stimulation.

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CHAPTER 2

Translation, Validity, and Reliability of the European Portuguese Version of the Touch Experiences and Attitudes Questionnaire

Chapter 2. Translation, Validity, and Reliability of the European Portuguese Version of the Touch Experiences and Attitudes Questionnaire

The work presented in Chapter 2 was published in PeerJ.

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Supplementary material can be found in Appendix A.

2.1. Abstract

Background. Positive touch experiences have proved to be extremely important throughout our lifespan, with cascading effects on our social life. However, few questionnaires are available to measure attitudes and experiences of touch in the Portuguese population. This study aimed to translate and validate the European Portuguese version of the Touch Experiences and Attitudes Questionnaire (TEAQ), as a reliable and valid instrument to measure different aspects of affective touch experiences and attitudes.

Methods. Therefore, an online sample of 384 (299 females and 85 males) participants, aged between 18 and 75 years (M = 24.59; SD = 9.56) was collected. Multidimensional Rasch model and confirmatory factor analysis were carried out, and also reliability and convergent and discriminant validity were determined. In addition, we examined sex differences in attitudes and experiences of touch.

Results. Results showed good fit indexes for the 52-item six-factor model structure (friends and family touch, current intimate touch, childhood touch, attitudes to selfcare, attitudes to intimate touch, and attitudes to unfamiliar touch). This instrument also showed good reliability and acceptable convergent and discriminant validity. Significant sex differences were found, with female participants reporting more positive touch experiences (including childhood touch, friends and family touch, and current intimate touch) and a more favourable attitude to self-care, with males showing a more positive attitude towards unfamiliar touch. Regarding attitudes towards the intimate touch, scores for both groups were comparable.

Conclusion. Overall, the European Portuguese version of the TEAQ presented good psychometric properties and appears to be a reliable and valid self-report measure, being a useful and beneficial instrument in research and clinical settings.

2.2. Introduction

Touch is an essential human need and plays a fundamental role in our social, emotional, and physical well-being throughout our entire life (Olausson et al., 2010). This sensory modality is fundamental from the early stages of life and plays an important role in the development of social relationships (Duhn, 2010; Gordon et al., 2010; Morrison et al., 2010; Moszkowski & Stack, 2007). It is the first communication channel to develop at the ontological level, and probably the most relevant route for the formation of affective attachment (Cascio et al., 2019; O. Miguel et al., 2020). Additionally, touch plays a protective factor for children, mitigating stress (Feldman et al., 2010; Stack & Muir, 1990) and social isolation response (Perkeybile & Bales, 2015). Touch can also have a neurodevelopment effect in children, provoking stronger brain activation in premature infants who have been involved in supportive touch experiences, leading to improvements in cognitive, motor, and language competencies (Maitre et al., 2017). Further evidence demonstrates the importance of positive touch experiences throughout the lifespan, shaping social reward, attachment, communication, and emotional regulation (Cascio et al., 2019).

Affective touch has been defined as tactile processing with a hedonic or emotional component (Morrison, 2016). This positive affective dimension of somatosensation is hypothesised to be primarily encoded by C-tactile afferents (CTs), a class of unmyelinated low-threshold mechanoreceptors that innervate the hairy skin of the body and have an optimised response to comforting and caress-like touch (Nordin, 1990; Olausson et al., 2010; Vallbo et al., 1993; Wessberg et al., 2003). Therefore, this system represents a specific neurobiological substrate for the rewarding properties of touch (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2002). Information conveyed by these receptors is transmitted to second-order projection neurons of the dorsal horn of the spinal cord (Marshall, 2022), following pathways that ultimately target emotion-related areas like the posterior insular cortex (Olausson et al., 2002).

While evidence indicates that the bottom-up mechanisms of affective touch rely on the role of CTs, top-down factors can also affect the perception of touch experiences. The literature suggests that expectations and contextual cues relating to the hedonic value of touch can modify somatosensory processing (Ellingsen et al., 2016). In this line, the role of oxytocin stands out, since is related to decreased stress responses and can increase the prominence of socially relevant cues, or promote approach behaviour in social interactions, thus also being context-dependent (Cascio et al., 2019; Kemp & Guastella, 2011; Shamay-Tsoory et al., 2009; Walker et al., 2017). The perception of touch can also be affected by sex, with females reportedly having more positive touch experiences throughout their lives

(Benenson et al., 1998; Berghout Austin & Braeger, 1990; Upenieks & Schafer, 2022; Webb & Peck, 2015), and tend to perceive these experiences as more pleasant during their lifespan (Croy et al., 2019; Jönsson et al., 2017; Russo et al., 2020). Comfort with social touch also depends on the kind of relationship we have with the other person (Suvilehto et al., 2015).

Abnormal processing or deprivation of social touch can be associated with a wide range of contextual factors. For example, childhood maltreatment is related to low ratings of touch valence and a preference for greater interpersonal distancing (Croy et al., 2016; Maier et al., 2020), while caregiver's touch deprivation (or avoidance) is related to an increased risk for sensory processing problems (Lin et al., 2005; Wilbarger et al., 2010). Furthermore, there is also evidence that deprivation and unsatisfactory levels of social contact are associated with a greater occurrence of depression (Cochrane, 1990; Debrot et al., 2021). Altered touch sensitivity has also been observed in several neurodevelopmental conditions, with the case of autism spectrum disorder (ASD) being of particular interest, since hypo- or hyper-sensitivity and avoidance of social contact are frequently reported symptoms (Cascio et al., 2016; Foss-Feig et al., 2012; Hyman et al., 2020; Kaiser et al., 2016). Finally, anhedonia towards affective touch has been observed in other disorders, such as anorexia nervosa or fibromyalgia (Boehme et al., 2020; Crucianelli et al., 2016), which emphasises the need for tools capable of reliably quantifying this sensory modality.

Currently, there are few tools that allow the evaluation of experiences or attitudes towards touch in the Portuguese population. One exception is the Social Touch Questionnaire (STQ) (Wilhelm et al., 2001), translated and validated for the Portuguese population by Vieira and colleagues (Vieira et al., 2016). The STQ measures perception, behaviours, and attitudes towards the social touch, with a focus on social interaction problems. Beyond revealing adequate reliability, the total scores of the STQ were positively correlated with the anxiety and avoidance subscales of the Social Interaction and Performance Anxiety and Avoidance Scale (SIPAAS) (Pinto-Gouveia et al., 2006). Despite its potential as a screening tool, there is a need for a test that assesses other relevant tactile dimensions, such as intimate touch and touch directed to oneself.

The Touch Experiences and Attitudes Questionnaire (TEAQ) (Trotter et al., 2018a) was developed to measure current touch experiences and previous experiences during childhood, as well as attitudes towards touch, thereby providing a holistic measure of touch experiences. The original version of TEAQ has an established and validated six-factor structure, covered by 57 items, namely Friends and Family Touch (FFT), Current Intimate, Touch (CIT), Childhood Touch (ChT), Attitude to Self-Care (ASC), Attitude to Intimate Touch (AIT), and Attitude to Unfamiliar Touch (AUT). Its validation evidenced a good internal

consistency (Cronbach's α ranged from .81 to .93), construct validity in terms of discriminant validity, known-group validity, and convergent validity, and criterion validity in terms of predictive and concurrent validity. In addition to the original version, a short-form version of TEAQ was also validated for the Russian population (Trotter et al., 2018b). Composed of 37 items, the short-form version revealed a reliable and validated model structure of five-factors, covering the dimensions of Attitude to Friendly Touch (AFT), ChT, ASC, CIT, and AIT (Cronbach's α ranged from .83 to .88), not reproducing the original dimension of AUT. It was also proposed the possibility to calculate a total score for this short-form version, through the sum of the subscale scores, which also revealed high reliability (Cronbach's α D .92). Recently, a 55 items Mongolian version was also validated (Tumurbaatar et al., 2022), which revealed a reliable and validated model structure of six-factors as the original version. Internal consistency of this version was well supported, with Cronbach's α ranging from .68 to .90.

To overcome the absence of a self-report measure that assesses current and previous experiences and attitudes towards touch over a diverse number of domains, the present study aimed to translate and validate the original English version of the TEAQ (Trotter et al., 2018a) for the European Portuguese population. For this purpose, we will test the six-factor model structure by performing a multidimensional Rasch model and a confirmatory factor analysis and by examining the reliability of the questionnaire, expecting a robust factor structure. Furthermore, we will assess convergent validity through the STQ (Vieira et al., 2016), as used in the original version, and we will assess discriminant validity through the NEO Five-Factor Inventory (NEO-FFI) (Magalhães et al., 2014), as in the Russian validation. We will also evaluate sex differences, expecting that female participants will have better attitudes towards touch, especially in dimensions such as ASC and FFT, as described in previous works (Trotter et al., 2018a, 2018b; Tumurbaatar et al., 2022). The validation of the European Portuguese version of TEAQ will provide a new tool with potential use in the clinical and research contexts.

2.3. Materials & Methods

2.3.1. Participants

A total of 384 participants completed the study, 299 were female (77.9%) and 85 (22.1%) were male. Age ranged from 18 to 75 years (M = 24.59; SD = 9.56). Demographic variables are described in Table 1. Inclusion criteria included being 18 years of age or older, being native European Portuguese speakers, and completing all questionnaires (TEAQ, STQ, and NEO-FFI). From an initial sample of 475, 73 participants were excluded for not completing all questionnaires, and 18 for not being native European Portuguese speakers. All the participants voluntarily agreed to answer the questionnaire and provided

written informed consent. None of the participants received any monetary compensation, and 67 university students received credits for their participation. The study protocol obtained approval from the ethics committee for Research in Human and Social Sciences of the University of Minho (CEICSH 023/2020) and was in accordance with the Declaration of Helsinki.

Table 1

Sociodemographic Characteristics of the Sample

	Total sample (N = 384)	Men (*n* = 85)	Women (*n* = 299)
Age	*M* (SD) 24.59 (9.56)	*M* (SD) 27.82 (12.57)	*M* (SD) 23.67 (8.31)
	n (%)	n (%)	n (%)
Education level (in years)			
≤ 4	1 (0.3)	1 (1.2)	-
5-11	211 (54.9)	40 (47.1)	171 (57.2)
≥ 12	172 (44.8)	44 (51.8)	128 (42.8)
Civil status			
Single	268 (69.8)	54 (63.5)	214 (71.6)
In a relationship	86 (22.4)	20 (23.5)	66 (22.1)
Married	25 (6.5)	10 (11.8)	15 (5)
Divorced/Widow	5 (1.3)	1 (1.2)	4 (1.3)
Professional situation			
Student	275 (71.6)	48 (56.5)	227 (75.9)
Full time employee	61 (15.9)	21 (24.7)	40 (13.4)
Part-time employee	7 (1.8)	2 (2.4)	5 (1.7)
Unemployed/Retired/Other	41 (10.7)	14 (16.5)	27 (9)
Household			
1	19 (4.9)	9 (10.6)	10 (3.3)
2-4	338 (88)	69 (81.2)	269 (90)
> 4	27 (7)	7 (8.3)	20 (6.7)
Children			
0	352 (91.7)	75 (88.2)	277 (92.6)
1	12 (3.1)	3 (3.5)	9 (3)
≥ 2	20 (5.2)	7 (8.2)	13 (4.3)

2.3.2. Measures

2.3.2.1. Sociodemographic Information. Participants completed a sociodemographic questionnaire assessing personal information, namely age, biological sex, nationality, educational level, civil status, number of people they live with, number of children, and professional situation.

2.3.2.2. Touch Experiences and Attitudes Questionnaire (TEAQ). The TEAQ (Trotter et al., 2018a) is a 57-items self-report questionnaire that reflects touch experiences at present and during childhood, as well as attitudes towards touch. The original version (UK validated) includes six subscales: Friends and Family Touch (FFT; with 11 items), relating to interpersonal touch experiences with friends and family; Current Intimate Touch (CIT; with 14 items), determines current levels of intimate touch experiences between people who are emotionally close or in a romantic relationship; Childhood Touch (ChT; with 9 items), provides a measure of positive childhood touch experiences; Attitude to Self-Care (ASC; with 5 items), related to skin care and grooming behaviours associated with positive self-care; Attitude to Intimate Touch (AIT; with 13 items), referring to attitudes towards touch experiences between people who are emotionally close or in a romantic relationship; and Attitude to Unfamiliar Touch (AUT; with 5 items), that relates to attitudes to touch experiences with someone that the individual is less close to, or even a stranger. Items are answered using a 5-point Likert scale ranging from 1 – 'Disagree strongly', 2 – 'Disagree a little', 3 – 'Neither agree nor disagree', 4 – 'Agree a little' to 5 – 'Agree strongly', with eight reverse-scored items. Therefore, higher scores reflect a more positive attitude toward touch or more frequent experiences. The total score for each subscale is obtained by calculating the mean score of the items for each subscale.

2.3.2.3. Social Touch Questionnaire (STQ). The STQ (Wilhelm et al., 2001; Portuguese version Vieira et al., 2016) is a 20-item self-report questionnaire that measures individual perceptions, behaviours, and attitudes toward the social touch. The items represent a vast variety of social interactions, such as touching versus being touched, touching someone you meet versus touching a stranger, touching someone in a public place versus in a private place, and touching without a sexual connotation versus touching with a sexual connotation. Each item is rated on a 5-point Likert scale to state how far the statements are true, ranging from 0 ('Not at all') to 4 ('Extremely'). The score ranges from 0 to 80 and results from the sum of the items, in which a low score represents the lowest avoidance of social touch, and a high score represents the most avoidance of social touch. The Portuguese version demonstrated

good internal consistency (Cronbach's α = .73). In the present study, this questionnaire had Cronbach's α = .82.

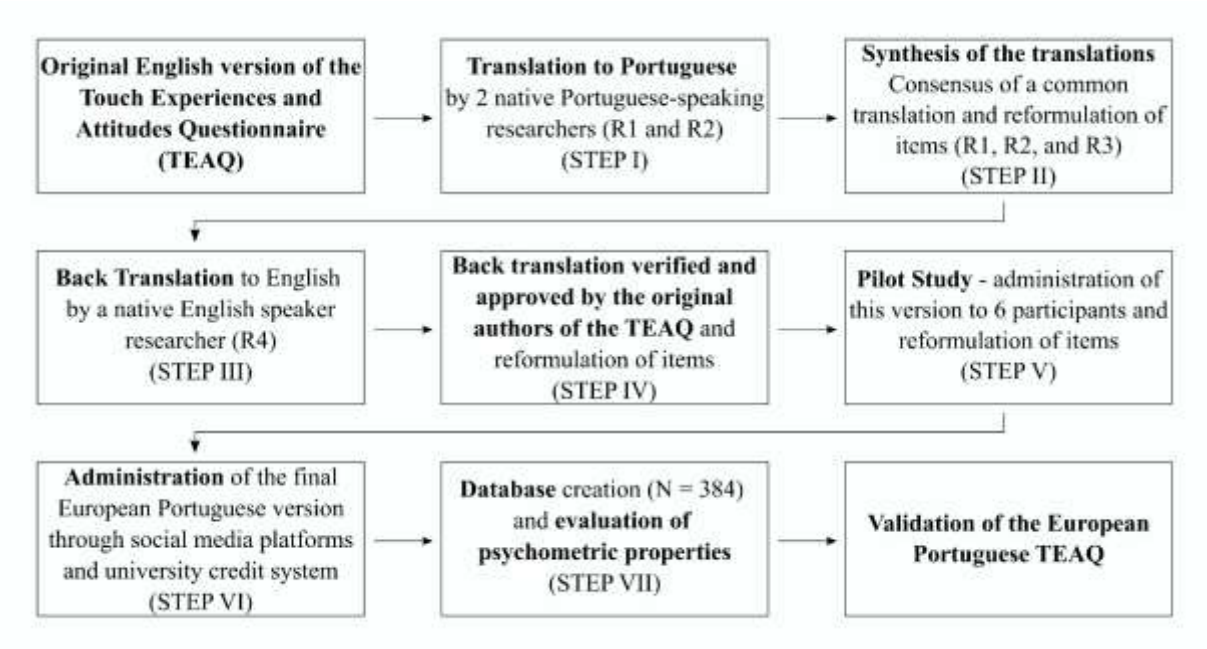
2.3.2.4. NEO Five-Factor Inventory (NEO-FFI). The NEO-FFI (McCrae & Costa, 1987; Portuguese version Magalhães et al., 2014) is a 60-item self-report inventory that assesses individual personality traits. The NEO-FFI is a short version of NEO PI-R and provides a concise measure of the five basic personality factors (Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness) with 12 items for each factor. Each item is measured on a 5-point Likert scale of agreement (0 – 'Strongly disagree', 1 – 'Disagree', 2 – 'Neither agree nor disagree', 3 – 'Agree', 4 – 'Strongly agree'). The score for each personality factor results from the sum of the respective 12 items. The Portuguese version demonstrated good internal consistency (with Cronbach's alpha values ranging from .71 to .81). In our study it had Cronbach's alpha values between .66 and .85.

2.3.3. Procedure

The translation of the original English version of the TEAQ to European Portuguese was performed following previous recommendations (see Figure 2) (Hilton & Skrutkowski, 2002). First, the original version of the TEAQ was translated to European Portuguese independently by two translators (psychology researchers), whose native language is European Portuguese. After that, a reconciled version was made by three researchers that compared the two versions of the translation and the original one and built a unique version. This version was back-translated from European Portuguese into English by a bilingual translator (psychology researcher), whose native language is English, and without any knowledge of the original items of the TEAQ. To analyse the equivalence between the original version and the retroversion, we also consulted the original authors. A preliminary version of the European Portuguese TEAQ was developed, and a pilot test was conducted with 6 individuals, 3 male and 3 female, aged between 22 and 25 (M = 23.83; SD = 1.07), to verify any difficulty or doubt when completing the items, and based on their feedback, a final version was developed and released (no changes were made). Participants were recruited via social media platforms and university credit system, through which they were asked to complete an online questionnaire conducted via Qualtrics software (Qualtrics, Provo, UT). All data were collected between April 2020 and January 2021. The final European Portuguese version of the TEAQ is included in Appendix A. The authors have permission to use this instrument from the copyright holders (Trotter et al., 2018a).

Figure 2

Flowchart of the European Portuguese Adaptation of the TEAQ



2.3.4. Statistical Analysis

The descriptive and inferential statistical analyses were conducted using IBM SPSS 28. The multidimensional Rasch model and the differential item functioning (DIF) were estimated using the ACER Conquest 5.19.5 software. Confirmatory factor analysis was carried out using IBM SPSS Amos™ 28.

To assess normality, we analysed the asymmetry values, skewness and kurtosis, revealing no significant biases in relation to the averages, with values lower than |3| and |10| for skewness and kurtosis, respectively (Kline, 2016). Also, to examine the suitability for conducting a confirmatory factor analysis (CFA), the factorability of the correlation matrix was explored. Bartlett's sphericity test proved to be statistically significant (p < .001) and the Kaiser-Meyer-Olkin (KMO) value was .90, above the recommended criterion of .60 (Pallant, 2011). An analysis of the correlation matrix also revealed several correlation coefficients greater than .30 (Tabachnick & Fidell, 2013).

The parameters of the multidimensional Rasch model were estimated with a marginal maximum likelihood estimation method for item parameters and a Monte Carlo-based approach with 2000 nodes for person parameters. Through this model, we obtained information about item fit, with the scores of the infit and outfit mean square (MNSQ) between .60 and 1.4 indicating that the item was fit for the model with Likert scales (Wright & Linacre, 1994). Items outside this range were removed from the questionnaire. Additionally, the performance of the 5-point Likert scale was examined using an outfit MNSQ < 2.0, demonstrating that the response category was functioning well (Linacre, 1999).

Furthermore, we examined the item separation reliability, in which values above .67 were considered acceptable (Utari et al., 2021). Finally, we obtained information about person separation reliability for each TEAQ subscale in the form of plausible values (PV) reliability indices, in which values above .70 were considered acceptable (Fauth et al., 2019).

The original six-factor model and the parcelled six-factor model of the TEAQ, as originally proposed by Trotter and colleagues (Trotter et al., 2018a), were tested through a CFA, according to the maximum likelihood method. The parcelled six-factor model was used since the reliability of structural equation modelling is reduced when there are a large number of variables. Using the item parcelling method (Nasser & Wisenbaker, 2003) to produce three measures for each factor, it was determined whether the model fit indexes would be affected, as suggested by Yang and colleagues (2010). In this procedure, the same item parcelling suggested by Trotter and colleagues (2018a) in the original version of this questionnaire was used, excluding only the items removed in the multidimensional Rasch model analysis. Thus, we explored if the parcelling method improved the criteria for a good model. The following indexes were considered to determine the goodness of model fit: Relative Chi-Square (x2/df), Normed Fit Index (NFI), Comparative Fit Index (CFI), Goodness-of-Fit Index (GFI), and Root Mean Square Error of Approximation (RMSEA). We considered values of Relative Chi-Square ≤ 5 acceptable fit and ≤ 2 perfect fit; NFI values ≥ .90 acceptable fit and ≥ .95 good fit; CFI values ≥ .90 acceptable fit, ≥ .95 good fit, and ≥ .97 perfect fit; GFI values between .85 and .89 acceptable fit, ≥ .90 good fit, and ≥ .95 perfect fit; and RMSEA values between .10 and .08 weak fit, ≤ .08 good fit, and ≤ .06 perfect fit. The Akaike Information Criterion (AIC) was also examined to compare models (Arbuckle, 2013; Hooper et al., 2008).

Additionally, internal consistency was assessed through Cronbach's alpha values, with values equal to or greater than .70 considered satisfactory (Bland & Altman, 1997; Streiner, 2003). We also computed Pearson's correlations between TEAQ subscales, and between TEAQ and the other questionnaires, namely the STQ (for convergent validity), and the NEO-FFI (for discriminant validity) ($r \leq |.12|$ – very weak correlation; $|.12| \geq r \geq |.24|$ – weak correlation; $|.24| \geq r \geq |.41|$ – moderate correlation; $|.41| \geq r \geq |1|$ – high correlation) (Lovakov & Agadullina, 2021). DIF was explored using the Rasch model method to compare differences in the functioning of individual items across the two groups (female and male participants), with the following criteria: DIF contrast < .50 logits – negligible DIF; DIF contrast between .50 and 1 logits – moderate DIF; and DIF contrast > 1 logits – substantial; if the DIF was substantial and significant it might mean that each group interprets the scale differently and that confounding factors are influencing that interpretation (Bond & Fox, 2015; Cameron et al., 2014). To examine sex differences in the TEAQ subscales, independent samples *t*-tests were performed, and effect-

sizes were measured through Cohen's *d* calculation (Cohen's *d*: ≥ .20 – small; ≥ .50 – medium; ≥ .80 – large) (Cohen, 1992).

2.4. Results

2.4.1. Multidimensional Rasch Model Analysis

Table 2 shows the statistics for the TEAQ items, including item difficulty location (endorsability) and item fit statistics. All items fit the multidimensional Rasch rating scale model, with the values of infit and outfit MNSQ within the acceptable range (.60 – 1.4). The location of items is in the range of -0.842 (Q1) to 1.020 (Q23) logits with an item separation reliability of .99. Item 1 ("Eu não gosto quando as pessoas são muito afetuosas fisicamente em relação a mim." [I dislike people being very physically affectionate towards me]) was the easiest to endorse (i.e., the easiest item for obtaining a score of 5) with its location at –0.842 logits, and item 23 ("Eu costumo tomar um duche ou um banho com alguém" [I often take a shower or bath with someone]) was the most difficult to endorse with its location at 1.020 logits. Five items (three items from the CIT subscale - items 23, 53, and 54 from the original version; one item from the ChT subscale - item 42 from the original version; and one item from the AIT subscale - item 20 from the original version) were excluded since the infit and outfit MNSQ values were not within the acceptable range. The item's threshold (τ) appeared in the analysis from the lowest to the highest ($\tau 1$ = -0.921; $\tau 2$ = -0.177; $\tau 3$ = -0.064; $\tau 4$ = 1.161). Additionally, person separation reliability in the form of PV reliability for each subscale were .97 for FFT, .93 for CIT, .93 for ChT, .82 for ASC, .87 for AIT, and .82 for AUT, all with acceptable criteria. The distribution of persons and the 52 items' threshold estimates on the different TEAQ subscales can be consulted in the wright map (see Figure 3). Therefore, after the multidimensional Rasch model analysis, the Portuguese TEAQ was left with 52 items: FFT (11 items) - 4, 13, 14, 16, 20, 28, 36, 45, 48, 51, and 52; CIT (11 items) - 11, 17, 18, 23, 25, 27, 34, 39, 42, 43, and 46; ChT (8 items) - 5, 6, 9, 15, 21, 30, 31, and 33; ASC (5 items) - 2, 7, 40, 49, and 50; AIT (12 items) - 8, 10, 12, 19, 22, 24, 29, 32, 38, 41, 44, and 47; AUT (5 items) - 1, 3, 26, 35, and 37; in which 1, 3, 9, 26, 35, and 37 are reverse-scored items.

Table 2

Item Measures and Fit Statistics for the TEAQ (52-items)

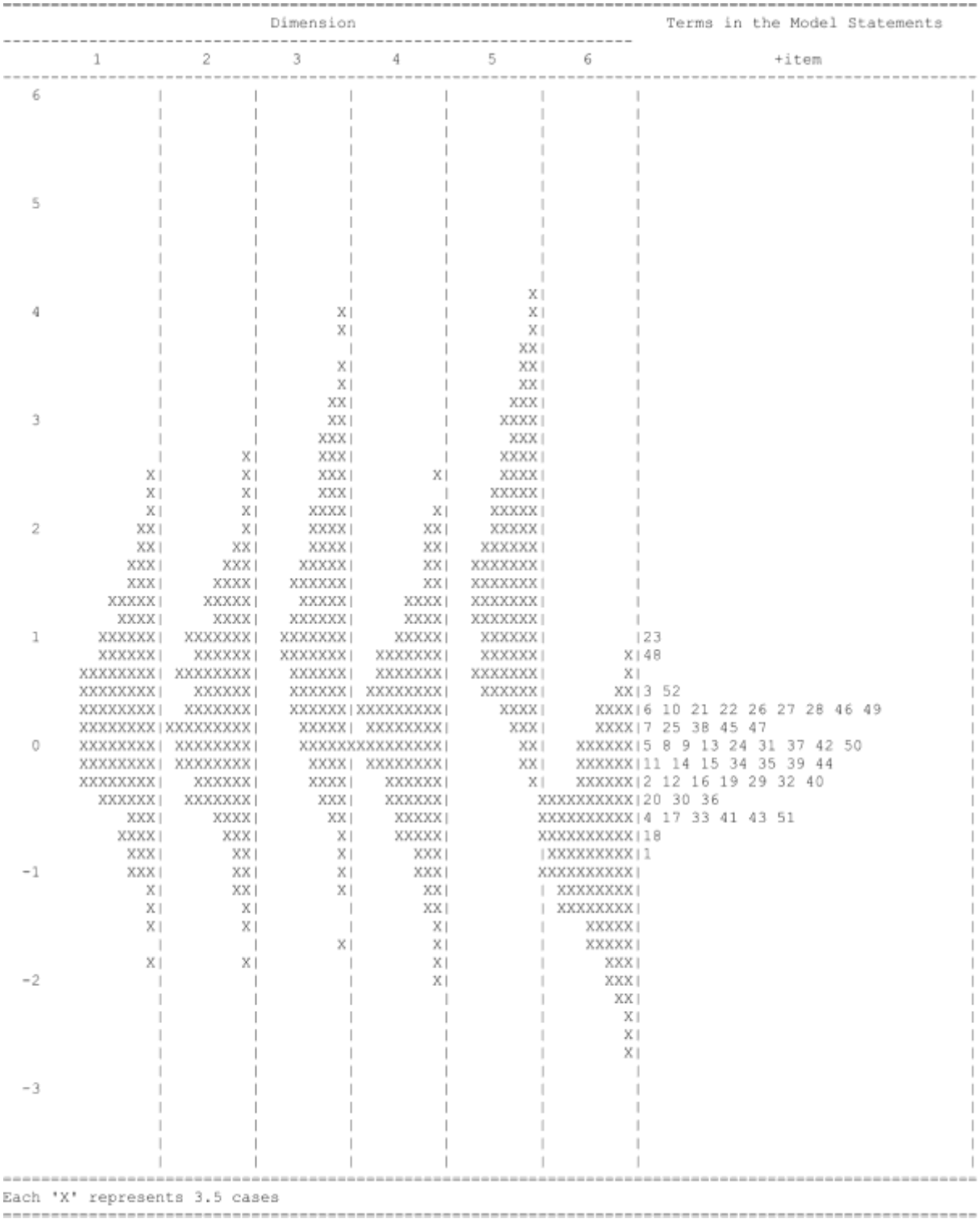
Item	Estimate	SE	Outfit MNSQ	Infit MNSQ
Factor 1: FFT				
Q4	-0.664	0.039	1.39	1.31
Q12	-0.242	0.049	0.78	0.86
Q13	0.144	0.037	0.99	1.00
Q15	-0.156	0.047	0.93	0.84
Q19	-0.205	0.049	1.26	1.10
Q27	0.381	0.037	1.34	1.23
Q43	-0.599	0.039	0.82	0.83
Q46	0.380	0.119	1.35	1.26
Q49	0.332	0.037	1.28	1.23
Q50	0.003	0.074	1.13	1.19
Factor 2: CIT				
Q10	0.492	0.044	1.17	1.09
Q16	-0.170	0.037	0.94	0.89
Q17	-0.511	0.038	1.08	1.11
Q22	0.453	0.045	0.91	0.75
Q24	0.016	0.047	1.16	1.11
Q26	0.476	0.040	0.91	0.96
Q33	-0.596	0.121	0.76	0.83
Q37	0.001	0.077	0.73	0.73
Q40	-0.272	0.037	0.93	0.92
Q41	-0.610	0.052	0.60	0.72
Q44	-0.038	0.048	0.75	0.78
Factor 3: ChT				
Q5	0.152	0.045	0.72	0.66
Q6	0.365	0.044	0.90	0.89
Q14	-0.141	0.037	0.96	0.97
Q20	-0.397	0.038	0.74	0.80
Q29	-0.302	0.049	0.79	0.84
Q30	-0.382	0.048	1.31	1.31
Q32	-0.228	0.049	1.00	0.88
Q38	0.288	0.046	0.95	0.86
Factor 4: ASC				
Q2	-0.292	0.037	0.89	0.90
Q7	0.230	0.037	0.83	0.83
Q39	-0.063	0.037	0.92	1.00
Q47	0.237	0.158	0.74	0.71
Q48	0.928	0.037	1.18	1.15
Factor 5: AIT				
Q8	0.138	0.046	1.20	1.11
Q9	0.152	0.045	1.00	0.97
Q11	-0.131	0.037	1.12	1.14
Q18	-0.780	0.039	1.15	1.14
Q21	0.420	0.044	1.20	1.19

Q23	1.020	0.037	1.39	1.37
Q28	0.374	0.037	0.78	0.80
Q31	0.045	0.046	0.65	0.66
Q36	-0.390	0.038	0.65	0.62
Q42	0.153	0.037	0.71	0.71
Q45	0.273	0.037	1.08	0.99
Factor 6: AUT				
Q1	-0.842	0.037	1.05	1.02
Q3	0.513	0.040	1.08	1.07
Q25	0.314	0.037	1.18	1.16
Q34	-0.163	0.037	1.25	1.24
Q35	-0.148	0.037	0.74	0.75

Note: SE – standard error; MNSQ – mean square.

Figure 3

Wright Map of TEAQ (52-items)



Note. Dimension 1 = FFT; Dimension 2 = CIT; Dimension 3 = ChT; Dimension 4 = ASC; Dimension 5 = AIT; Dimension 6 = AUT.

2.4.2. Confirmatory Factor Analysis and internal Consistency

Results of the 52-items confirmatory factor analyses for the original and the parcelled six-factor model are reported in Table 3. Examination of the goodness of fit indexes of competing models revealed that the parcelled six-factor model had a good fit to data (see Table 3 and Figure 4), as observed by the authors of the original version of the TEAQ (Trotter et al., 2018a). The six factors of the TEAQ revealed good to excellent values of internal consistency, with the exception of AUT subscale, which revealed acceptable internal consistency (FFT, α = .90; CIT, α = .88; ChT, α = .90; ASC, α = .81; AIT, α = .89; AUT, α = .78).

Table 3

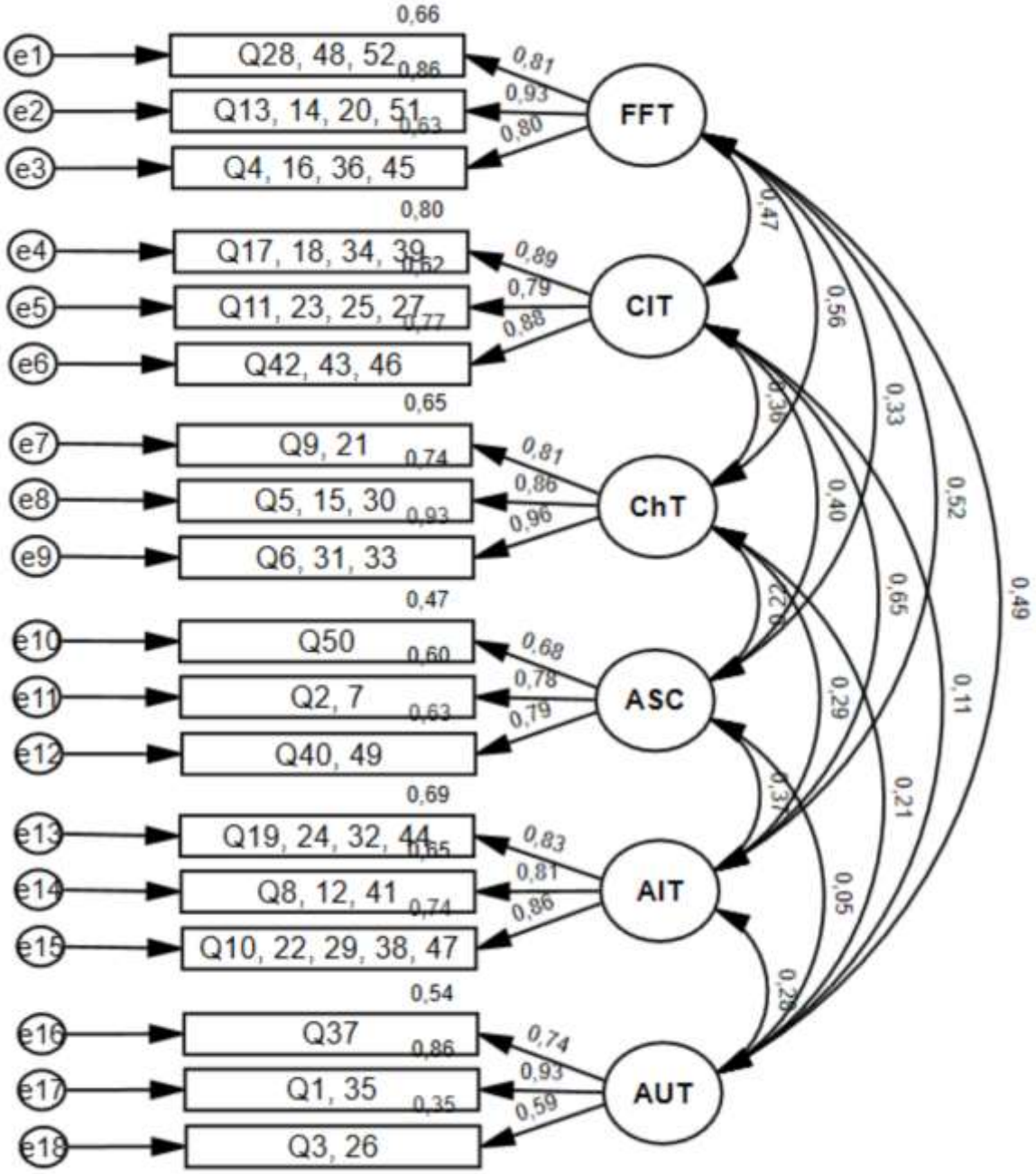
Model Fit Index

Model	χ^2	df	χ^2/df	NFI	CFI	GFI	RMSEA	AIC
Original	3507,44	1261	2,78	.70	.78	.71	.07	3743,435
Parcelled	342,67	120	2,86	.92	.95	.91	.07	444,667

Note. χ^2 – Chi-Square; df – degrees of freedom; NFI – Normed Fit Index; CFI – Comparative Fit Index; GFI – Goodness-of-Fit Index; RMSEA – Root Mean Square Error of Approximation; AIC – Akaike Information Criterion.

Figure 4

Confirmatory Factor Analysis for the Parcelled Six-Factor Model of TEAQ (52-items)



2.4.3. Correlations Between Subscales

All TEAQ subscale scores correlated significantly with each other, except the AUT with the CIT and ASC subscales (see Table 4). Significant high correlations were found between FFT and CIT ($r = .42$; $p < .001$), FFT and ChT ($r = .50$; $p < .001$), FFT and AIT ($r = .46$; $p < .001$), and CIT and AIT ($r = .58$; $p < .001$) subscales. Significant moderate correlations were found between FFT and ASC ($r = .30$; $p < .001$),

FFT and AUT (r = .40; p < .001), CIT and ChT (r = .32; p < .001), CIT and ASC (r = .34; p < .001), ChT and AIT (r = .26; p < .001), and ASC and AIT (r = .31; p < .001) subscales. Significant weak correlations were found between ChT and ASC (r = .21; p < .001), ChT and AUT (r = .15; p < .01), and AIT and AUT (r = .19; p < .001) subscales. The strongest correlation was observed between CIT and AIT (r = .58), and the weakest significant correlation between ChT and AUT (r = .15).

Table 4

Pearson's r Correlation Coefficient Between Each TEAQ Subscales

	FFT	CIT	ChT	ASC	AIT	AUT
Friends and family touch (FFT)	-	.42***	.50***	.30***	.46***	.40***
Current intimate touch (CIT)	-	-	.32***	.34***	.58***	.09
Childhood touch (ChT)	-	-	-	.21***	.26***	.15**
Attitude to self-care (ASC)	-	-	-	-	.31***	.01
Attitude to intimate touch (AIT)	-	-	-	.-	-	.19***
Attitude to unfamiliar touch (AUT)	-	-	-	-	-	-

Note. *** p < .001; ** p < .01.

2.4.4. Correlations with Other Scales: Convergent and Discriminant Validity

Regarding convergent validity, the STQ and TEAQ subscales correlations were significant (p < .001). These results revealed high correlations with FFT (r = -.59), AIT (r = -.43), and AUT (r = -.70) subscales, moderate correlations with CIT (r = -.25), and ChT (r = -.31) subscales, and a weak correlation with ASC (r = -.19) subscale (see Table 5). Concerning discriminant validity, we made correlations between the five personality factors of NEO-FFI and the TEAQ subscales (see Table 5). For the Neuroticism (N) factor, a moderate correlation was found with the AUT (r = -.29; p < .001) subscale, and weak correlations with the FFT (r = -.16; p < .01), CIT (r = -.12; p < .05), and ChT (r = -.15; p < .01) subscales, but no significant correlations with ASC and AIT. For the Extraversion (E) factor, a high correlation emerged with the FFT (r = .45; p < .001) subscale, moderate correlations with the CIT (r = .35; p < .001), ChT (r = .30; p < .001), AIT (r = .35; p < .001), and AUT (r = .34; p < .001) subscales, and a weak correlation with the ASC (r = .15; p < .01) subscale. For the Openness to Experience (O) factor, we observed a moderate correlation with the AIT (r = .25; p < .001) subscale, and a very weak correlation with the FFT (r = .11; p < .05) subscale, but no significant correlations with the CIT, ChT, ASC, and AUT. For the Agreeableness (A) factor, moderate correlations were observed with FFT (r = .34; p < .001), ChT (r = .27; p < .001), and AIT (r = .32; p < .001) subscales, and weak correlations with the CIT (r = .21; p < .001), ASC (r = .14; p < .01), and AUT (r = .17; p < .001) subscales. Lastly, for the Conscientiousness (C) factor, a moderate correlation was found with the CIT (r = .25; p <.001) subscale, and weak correlations with the FFT (r =

.19; $p < .001$), ChT ($r = .16$; $p < .01$), ASC ($r = .19$; $p < .001$), and AIT ($r = .23$; $p < .001$) subscales, but no correlation with AUT.

Table 5

TEAQ Subscales Correlations with STQ and NEO-FFI

	FFT	CIT	ChT	ASC	AIT	AUT
STQ	-.59***	-.25***	-.31***	-.19***	-.43***	-.70***
N (NEO-FFI)	-.16**	-.12*	-.15**	.06	.00	-.29***
E (NEO-FFI)	.45***	.35***	.30***	.15**	.35***	.34***
O (NEO-FFI)	.11*	.03	.06	.09	.25***	.03
A (NEO-FFI)	.34***	.21***	.27***	.14**	.32***	.17***
C (NEO-FFI)	.19***	.25***	.16**	.19***	.23***	-.01

Note. STQ – Social Touch Questionnaire; N – Neuroticism; E – Extraversion; O – Openness to Experience; A – Agreeableness; C – Conscientiousness; FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch; * $p < .05$; ** $p < .01$; *** $p < .001$.

2.4.5. Sex Differences on TEAQ

No substantial DIF was found in the TEAQ items across female and male participants. Moderate DIF was found for item 3 – "Eu tenho de conhecer alguém relativamente bem para desfrutar do seu abraço." [I have to know someone quite well to enjoy a hug from them] (i.e., relatively easier for males than females [0.608 logits]), item 24 – "Eu gosto de fazer sexo." [I enjoy having sex] (i.e., relatively easier for males than females [0.636 logits]), item 26 – "Eu não gosto de ter proximidade física com pessoas que não conheço bem." [I am put off by physical familiarity] (i.e., relatively easier for males than females [0.622 logits]), item 37 – "Faz-me sentir desconfortável se alguém que eu não conheço muito bem me toca de uma maneira amigável." [It makes me feel uncomfortable if someone I don't know very well touches me in a friendly manner] (i.e., relatively easier for males than females [0.528 logits]), item 40 – "Eu gosto de exfoliar a minha pele." [I like exfoliating my skin] (i.e., relatively easier for females than males [0.532 logits]), and item 50 – "Eu gosto de usar máscaras faciais na minha pele." [I like to use face masks on my skin] (i.e., relatively easier for females than males [0.954 logits]). All other items have DIF < .50, and item 19 – "Beijar é uma boa forma de expressar atração física." [Kissing is a great way of expressing physical attraction] revealed the same level of difficulty for both groups. These findings show that, regardless of other variables, the items performed similarly for people with the same level of ability.

Table 6 shows the sex differences on TEAQ subscales. Females showed higher scores on FFT, CIT, ChT, and ASC subscales than males, with a large effect size on all the subscales. AIT subscale scores for

female and male participants were comparable. AUT subscale scores were higher for males than females, with a large effect size.

Table 6

T-test Results for Sex Differences Across TEAQ Subscales

	Male (n = 85) *M* (SD)	Female (n = 299) *M* (SD)	*t*(df)	*p*-value	Cohen's *d*	95% CI
FFT	3.15 (.89)	3.42 (.87)	-2.50 (382)	.01*	.88	-.549; -.065
CIT	3.13 (.86)	3.49 (.86)	-3,45 (382)	< .001***	.86	-.667; -.181
ChT	3.73 (.88)	3.96 (.89)	-2,06 (382)	.04*	.89	-.494; -.011
ASC	2.36 (.83)	3.52 (.89)	-10,79 (382)	< .001***	.87	-1.584; -1.067
AIT	4.20 (.63)	4.33 (.59)	-1,71 (382)	.09	.60	-.452; .031
AUT	2.62 (.87)	2.18 (.78)	4.48 (382)	< .001***	.80	.306; .794

Note. FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch; *M* – mean; SD – standard deviation; df – degrees of freedom; CI – Confidence Interval; * $p < .05$; *** $p < .001$.

2.5. Discussion

The present study explored the psychometric properties of the 52-items European Portuguese version of the TEAQ. The original version proposes a six-factor structure (Trotter et al., 2018a), which also proved to be appropriate for the Portuguese version. A multidimensional Rasch model and a confirmatory factor analysis showed good fit index values for the 52-items six-factor model, demonstrating that all dimensions mentioned above can be assessed through this version of the questionnaire. Regarding instrument reliability, the Portuguese version of the TEAQ revealed high Cronbach's α values, and overall, demonstrated good to excellent levels of internal consistency for the six factors individually.

All TEAQ subscales positively correlated with each other, except for the attitude to unfamiliar touch with current intimate touch and attitude to self-care, in which no significant correlation emerged. The weakest significant correlation observed was between childhood touch experiences and attitude to unfamiliar touch, and the strongest significant correlation was between current intimate touch and attitude to intimate touch. Despite cultural differences, these results are in line with the results found in the other available versions of the questionnaire (Trotter et al., 2018a, 2018b). In similarity with our results, one of the weakest correlations found in the original version (Trotter et al., 2018a) was between attitude to unfamiliar touch and childhood touch experiences. The same applies to the strongest correlation between current intimate touch and attitude to intimate touch, being the strongest correlation in the UK version (Trotter et al., 2018a), and also one of the strongest correlations in the Russian version (Trotter et al., 2018b). Moreover, the factor of unfamiliar touch attitudes was the only factor that was not reproduced in

the Russian short-form version (Trotter et al., 2018b), and is also globally our factor with the lowest values.

Concerning the validity of the questionnaire, acceptable convergent validity has been demonstrated with the STQ (Vieira et al., 2016) and all TEAQ subscales, in which the correlations were negative, being the attitude to unfamiliar touch factor the strongest correlation. This finding was expected since the STQ was developed to assess anxiety with social touch situations, including situations involving contact with strangers. Furthermore, the lowest correlations were with the CIT and ASC subscales, since they are dimensions not covered in the STQ. This is in accordance with the original version, in which the AUT subscale revealed the strongest correlation, and the ASC subscale revealed the lowest correlation. Moreover, acceptable discriminant validity was demonstrated with NEO-FFI (Magalhães et al., 2014), with most TEAQ subscales showing very weak, weak, or no significant correlation (19 out of 30; 63.33%) with the NEO-FFI factors, although there are some moderate correlations (10 out of 30; 33.33%) and a high correlation (3.33%). The strongest correlation was between the friends and family touch subscale and the extraversion factor, in accordance with the Russian version (Trotter et al., 2018b).

Regarding the effects of sex on experiences and attitudes towards touch, we found that females scored higher than males on the subscales about touch experiences at present and during childhood (FFT, CIT, and ChT subscales), suggesting that females experience more positive physical touch than males during their lifetime. These differences go in the same direction as those found in previous versions in the TEAQ (Trotter et al., 2018a, 2018b). Moreover, there results are in line with previous research reporting that mothers tend to have a closer physical relationship with their daughters than with their sons (Benenson et al., 1998), and females have more positive touch experiences than males during adulthood (Webb & Peck, 2015), and in later life (Upenieks & Schafer, 2022). This greater involvement of females in touch experiences can be explained by their higher involvement in social activities (Upenieks & Schafer, 2022) and by their tendency to perceive these positive touch experiences as more pleasant compared to males during their lifespan (Croy et al., 2019; Jönsson et al., 2017; Russo et al., 2020). Concerning attitude to self-care (ASC subscale), female participants also scored significantly higher than males, suggesting that females have a more positive attitude towards self-care, also in agreement with what was found in previous TEAQ versions (Trotter et al., 2018a, 2018b; Tumurbaatar et al., 2022). Research has shown that females report their appearance to be more important than males (Quittkat et al., 2019) and have more self-evaluative and motivational investment in themselves (Cash et al., 2004). Accordingly, females also demonstrated greater concern with disease-related self-care (Hoffman et al., 2021; Sousa et al., 2020). However, attitude to intimate touch (AIT subscale) scores were comparable

between female and male participants, which is in line with what was reported by Guerrero and colleagues (Guerrero & Andersen, 1991) in a study with couples, and also with the English and Mongolian TEAQ versions (Trotter et al., 2018a; Tumurbaatar et al., 2022). Finally, males scored higher than females in terms of positive attitude to unfamiliar touch (AUT subscale), which supports previous findings that females avoid and find the touch of strangers more unpleasant than males (Hertenstein et al., 2006).

Irrespective of current findings, some limitations should be considered. First, the data was collected during the outbreak of the COVID-19 pandemic, which can influence the way people perceive interpersonal touch due to the social distancing measures imposed. However, the validity and reliability of the questionnaire do not appear to have been affected by this factor, since the present values are in agreement with those obtained in the original version. Nevertheless, it may be important to reevaluate the questionnaire after the pandemic is over, exploring possible differences in post-pandemic touch experiences. Also, the majority of the participants were female, single, and with no children, which can make it difficult to obtain a representative sample of the population. Additionally, most participants were young adults (average age below 30), which limits generalisation to older people. This limitation may also be related to the fact that the evaluation was conducted online which limits access to the population with the capacity to use computer applications. Such sampling biases should be taken into account since these are variables that can affect the perception of affective touch. In this respect, previous work has shown a positive correlation between age and pleasantness in the affective touch dimension (Sehlstedt et al., 2016), nevertheless Trotter and colleagues (2018a) reported a lack of effect of age on TEAQ subscale scores; married people have higher scores on the CIT scale of the TEAQ (Trotter et al., 2018b; Tumurbaatar et al., 2022); and, as previously discussed, female have more positive touch experiences and perceive affective touch as more pleasant (Russo et al., 2020). In future investigations, it could also be beneficial to conduct a discriminant analysis comparing with clinical groups such as ASD, anorexia nervosa, or chronic pain patients.

2.6. Conclusions

Overall, the European Portuguese version of the TEAQ demonstrated good psychometric properties. This instrument allows the measurement of both touch experiences (i.e., with friends and family, intimate touch, and during childhood) and attitudes towards touch (i.e., related to self-care, intimate touch, and unfamiliar touch). Therefore, this questionnaire will be a new instrument that can increase knowledge about affective touch and could be beneficial for its application in research and clinical settings, facilitating the assessment interactions between attitudes/experiences towards this sensory modality and other

psychosocial and neurobiological dimensions in healthy participants, and how they may be altered in clinical populations. It will also allow us to discriminate the role of past and present attitudes/experiences of touch in the normal and pathological development of individuals.

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CHAPTER 3

Brain Oscillatory Dynamics During Discriminative vs CT-Optimal Touch

Chapter 3. Brain Oscillatory Dynamics During Discriminative vs CT-Optimal Touch

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In addition, results from this empirical work were presented as a poster presentation at the Festival of Touch, held from July 4th to 7th at the Campus Saint-Charles of Aix-Marseille University, in Marseille, France. This international conference was a joint meeting of two major research networks in the field of this work – Research in Touch and IASAT: International Association for the Study of Affective Touch – and brought together researchers from around the world working on the sense of touch.

Poster Presentation Reference:

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3.1. Abstract

The affective dimension of touch is conveyed by low-threshold mechanoreceptors known as C-Tactile (CT) afferents. Literature has shown that the stimulation of these fibres appears to have an important modulatory function in neural oscillations. However, much remains to be explored in this field. This study aims to provide background knowledge about the brain oscillatory dynamics and spatial field distributions of CT stimulation, by comparing the brain's spectral power and the microstates to affective (stroking) vs discriminative touch (vibration) conditions. Thirty-four healthy participants (18 female) received tactile stimulation with a cosmetic brush at CT-optimal speeds or vibrotactile stimulation (at around 200 Hz) on the left forearm's dorsum. They evaluated the pleasantness and intensity ratings of the stimulation while an electroencephalogram was recorded. Stroking stimulation was rated as more pleasant than the vibrotactile stimuli, with no significant differences in the intensity ratings. Power spectral density results revealed reduced power in alpha/mu and beta bands in central/Rolandic areas for the stroking condition compared to the vibration condition. Microstates analysis showed a reduced prevalence of class A and an increased prevalence of classes B and D during stroking. These findings indicate that CT-tuned stroking increased sensorimotor cortical excitability and engaged greater attentional resources, suggesting that this form of touch may be a prioritised type of information.

3.2. Introduction

Touch experiences significantly impact our well-being. Discriminative touch involves sensory perception and identification, such as texture, pressure, and vibration, and is mediated by Aβ fibres. In contrast, affective touch concerns the most emotional and pleasant domains of touch, mediated by C-Tactile (CT) afferents (McGlone et al., 2007, 2014; Morrison et al., 2010, 2016). Affective touch is crucial throughout our lifespan, influencing our development as individuals (Brauer et al., 2016), as well as in our everyday somatosensory experiences, significantly shaping social relationships (Cascio et al., 2019; Morrison et al., 2010; Walker & McGlone, 2013).

Over the past few decades, a somatosensory system related to affective dimensions of touch has been extensively described in the literature (McGlone et al., 2007, 2014; Morrison et al., 2010; Olausson et al., 2010; Vallbo et al., 1999). These affective aspects of touch are conveyed through a subclass of low-threshold mechanoreceptive C-fibres, known as C-Tactile (or CT), which are located mainly on the hairy skin of the body (Nordin, 1990; Olausson et al., 2010; Vallbo et al., 1993, 1999). CT afferents are particularly sensitive to gentle and caress-like stroking touch (Olausson et al., 2010; Vallbo et al., 1993), responding optimally to slow-moving stimuli (i.e., between 1-10 cm/s) (Ackerley et al., 2014a; Löken et al., 2009; Olausson et al., 2016), and human skin temperatures (about 32°C) (Ackerley et al., 2014). CT-optimal speeds are often positively correlated with touch pleasantness perception (Ackerley et al., 2014; Essick et al., 1999, 2010; Löken et al., 2009). These fibres respond poorly to rapid events and vibration, and are not optimised for discriminative touch (e.g., pressure, texture, localisation) (McGlone et al., 2014). The input from CT afferents reaches cortical areas such as the posterior insular cortex, which is involved in affective and social processing. Additionally, affective touch engages other cortical regions, including the parietal operculum and other somatosensory-related areas, highlighting the distributed nature of its processing network (Graziano & Jones, 2004; McGlone et al., 2014). In contrast, discriminative touch information projects to the somatosensory cortex (McGlone et al., 2014).

A promising approach to studying the large-scale neural processing associated with CT-mediated touch could be through Electroencephalogram (EEG) microstate analysis. Microstates are brief periods of quasi-stability scalp topographies, during which the global brain activity remains relatively consistent before undergoing abrupt transitions to a different configuration. These transitions reflect dynamic shifts in large-scale neural network activity (Koenig et al., 1999). These states correspond to the synchronized activation of large-scale neural networks (Michel et al., 2009; Michel & Koenig, 2018). The literature consistently identifies four prototypical microstate topographies (or classes), labelled A to D, each with a functional significance: A (temporal regions), related to auditory processing and person's

arousal/arousability; B (occipital regions), linked to visual processing; C (anterior cingulate cortex and inferior frontal regions), related to the processing of self-referential internal mentation, and interoceptive-automatic processing; and D (fronto-parietal regions), linked to attention-related processing and executive functioning (Schiller et al., 2023). This approach provides a valuable complement to waveform analysis, as it does not depend on a priori selections of the reference, electrodes, or time points. Although microstates have been applied in social and affective neuroscience (e.g., EEG microstates analysis during sustained pain; Qiu et al., 2023), no studies have linked them specifically to affective touch (Schiller et al., 2023).

In accordance, brain rhythms are affected by different types of somatosensory input (Baker, 2007; Buchholz et al., 2014; Liberati et al., 2018), for instance, oscillatory dynamics, particularly in the alpha and beta bands, are modulated by tactile stimulation. Alpha-band oscillations have shown decreased activity over somatosensory areas following tactile stimulation, primarily for discriminative touch (Michail et al., 2016; Singh et al., 2014). Similarly, tactile stimulation on the forearm consistently leads to beta band suppression in somatosensory areas (Singh et al., 2014; Von Mohr et al., 2018). These findings underscore the modulatory function of tactile stimulation on neural oscillations. Von Mohr et al. (2018) expanded previous works by examining CT-optimal (affective) touch; further EEG analysis, like microstate analysis, could reveal the broad neural dynamics correlated with this somatosensory modality. The scarcity of research on how CT stimulation specifically modulates brain oscillatory activity, combined with the methodological variability across studies, highlights the need for further systematic and comprehensive exploration of this relationship.

Individual differences in touch-related attitudes and experiences are important factors influencing the perception of affective touch. These differences can be assessed using the Touch Experiences and Attitudes Questionnaire (TEAQ; Pereira et al., 2023), which measures attitudes toward and experiences of touch in contexts such as intimate relationships, childhood experiences, and interactions with less familiar individuals. Positive attitudes and frequent experiences of touch have been associated with enhanced perceptions of affective touch (Pereira et al., 2023; Triscoli et al., 2017).

The main aim of the present study was to characterize the brain oscillatory dynamics and spatial field distributions of CT afferent stimulation. This study extends prior research by focusing on the large-scale neural signatures of affective touch (using stimulation of the CT fibres through stroking with a soft brush at CT optimal speeds) vs discriminative touch (using vibrotactile stimulation through a linear resonant actuator at approximately 200 Hz), emphasising EEG microstate analysis to uncover previously unexplored neural dynamics. The inclusion of both oscillatory and microstate analysis provides a novel

assessment of the neural mechanisms underlying these two forms of touch. The vibration condition was used to ensure that the observed brain signatures were specific to the affective touch, rather than common attentional mechanisms. We hypothesise that participants will evaluate the brushing condition as more pleasant than the vibrating condition, consistent with previous findings, and no differences in the intensity ratings, used as a control measure to confirm that the perceived intensity was similar across conditions. Regarding touch-related attitudes and experiences, we hypothesised that individuals with higher scores on TEAQ subscales, reflecting positive attitudes and greater touch frequency, would rate CT-optimal stroking as more pleasant, highlighting the influence of personal touch history on the hedonic evaluation of affective touch. Regarding the oscillatory power, we expected to observe a power suppression of alpha/mu and beta bands in the stroking condition compared to the vibration condition over the somatosensory area, aligning with prior literature. Finally, we expected that the parameters of the four prototypical microstates would be sensitive to the type of stimulation.

3.3. Methods

3.3.1. Participants

The sample consisted of 34 healthy young adults (18 females and 16 males) aged 18 to 39 years (M = 22.62; SD = 5.22). We selected our sample size based on available resources and its similarity to those employed in prior research within this field. All participants reported normal or corrected-to-normal vision. Participants were excluded if they had any wounds on the left arm, a history of head injury, or any current neurological or psychiatric condition. All 34 participants were included in the behavioural and PSD analyses; however, 3 participants were excluded from the microstate analysis due to artifacts in their EEG recordings, resulting in a final sample of 31 participants for this analysis. Further demographic details of the sample can be found in Table 7. Participants were recruited from the University of Minho's course credit system and received academic credit for participation. Written informed consent was obtained from all participants. The study followed the Declaration of Helsinki's ethical guidelines and received approval from the University of Minho's Health and Life Sciences Research Ethics Committee (CEICSH 023/2020).

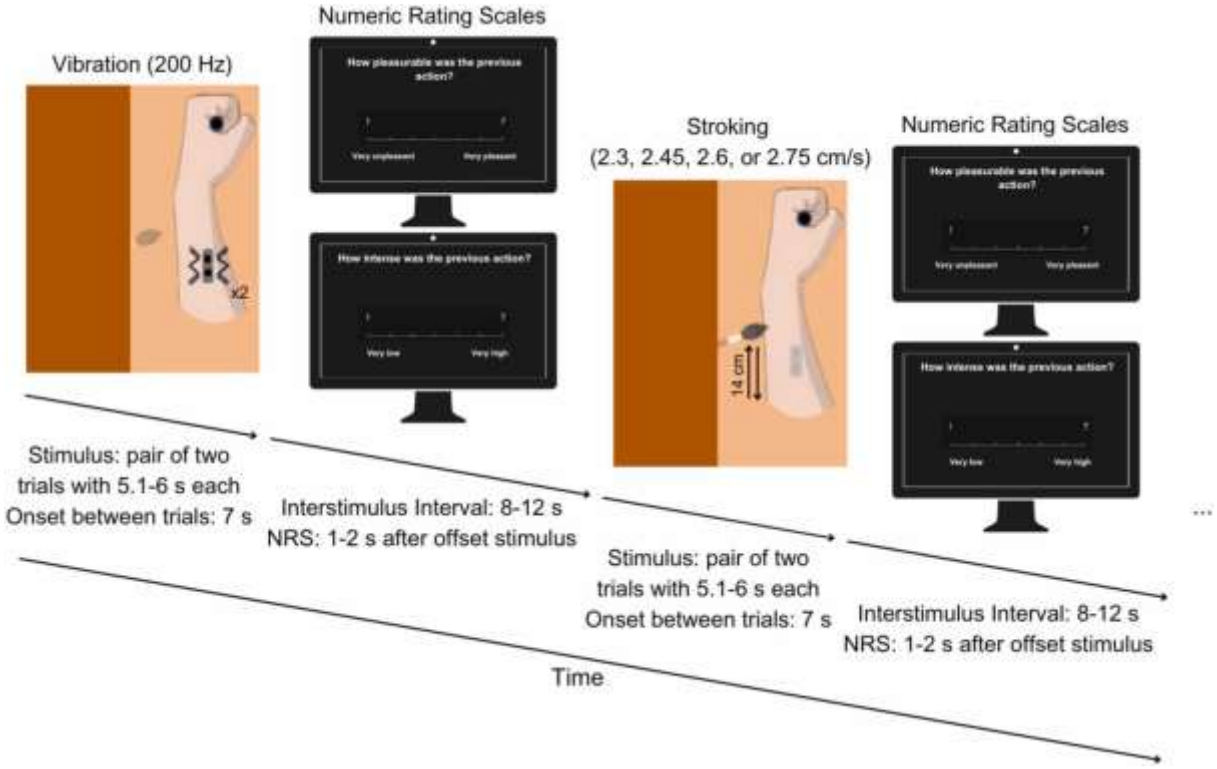
3.3.2. Experimental Task

A schematic figure representing the experiment methodology is presented in Figure 5. The task consisted of stroking stimulation with a soft brush (a standard method to activate CT fibres) attached to the end of the stimulator arm, a dynamic movement at CT-optimal speeds along a 14 cm path in the forearm dorsum, or vibrotactile stimulation (using a linear resonant actuator (LRA) at around 200 Hz),

delivered at a fixed location also on the forearm. The LRA were mounted in a 3D printed plastic plate with dimensions of 6*2.5 cm and attached to the left arm of the participant using adhesive tape. The location was the same across all the participants for both stimuli. These stimuli were presented in 25 pairs of trials for each condition (making a total of 50 stimulations per condition). Each pair of trials consisted of two strokes with the brush (proximal to distal and distal to proximal; at speeds of approximately 2.3cm/s, 2.45cm/s, 2.6cm/s, or 2.75cm/s) or two discrete vibrotactile stimuli. The order of conditions within the blocks was pseudorandomized to ensure a balanced presentation and to minimize anticipatory effects. The four velocities of stroking and four durations of vibrotactile stimulation were also randomized within blocks, with constraints applied to prevent the consecutive repetition of the same velocity or duration, or more than 2 consecutive repetitions of the same condition. Each stimulus, either vibration or stroking, could last 5.1s, 5.4s, 5.7s, or 6s. These durations depended on the time it took the brush to travel the 14 cm at the four different stroking speeds, and these different durations were also used in the vibration to match between conditions. The onset of the second stimulus of the pair was always 7 seconds after the onset of the first stimulus and the interval between pairs was a random value from 8-12 seconds, in order to reduce sensory adaptation and allow participants to respond to the numeric rating scales. Both types of stimulation were performed using an Arduino-based stimulator developed in-house. During the initial briefing, participants were instructed to focus on the somatosensory stimuli during each trial and to rate its pleasantness and intensity afterward using numeric rating scales (NRS). These scales utilised a 7-point Likert format, ranging from 1 (‘Very unpleasant’/’Very low’, respectively) to 7 (‘Very pleasant’/’Very high’, respectively), including one decimal place. The midpoint of the scale (4.0) was explained as a neutral response. Pleasantness and intensity ratings were collected consecutively and in the same order, with a 1-2 second delay following the offset of the second stimulus of the block.

Figure 5

Schematic Figure Representing the Experiment Methodology



3.3.3. Procedure and Psychosocial Assessment

Participants initially completed a socio-demographic questionnaire, an EEG checklist, and the Touch Experiences and Attitudes Questionnaire (TEAQ; Pereira et al., 2023). This questionnaire assesses current and childhood touch experiences, and attitudes toward touch. The Portuguese version comprises 52 items grouped into six subscales: Friends and Family Touch (FFT), which examines interpersonal touch experiences within family and friend contexts; Current Intimate Touch (CIT), which assesses the frequency of intimate touch in close emotional or romantic relationships; Childhood Touch (ChT), which measures positive touch experiences in childhood; Attitude to Self-Care (ASC), related to grooming and skincare and grooming as indicators of self-care; Attitude to Intimate Touch (AIT), which reflects attitudes towards touch in close, emotional relationships; and Attitude to Unfamiliar Touch (AUT), which relates to attitudes toward touch from less familiar individuals or stranger. Responses were provided on a 5-point Likert scale from 1 ('Disagree strongly') to 5 ('Agree strongly'). Each subscale score represents the mean of its items, with higher scores indicating more positive attitudes toward touch or greater frequency of touch experiences.

Following questionnaire completion, participants were fitted with the EEG cap and seated in a soundproof room, positioned one meter away from the display screen. Participants placed their left arm

on the stimulator with the brush. The vibration plate was also attached to their left arm. Before the experimental task, participants underwent a calibration procedure to match the perceived intensity of vibrotactile and stroking stimuli. During this process, they were presented with stroking at approximately 2.5cm/s and asked to adjust the vibration intensity until it matched their subjective perception of the stroking intensity. The intensity of the vibrotactile stimulation was matched using a visual analog scale (VAS) presented on the computer screen, where participants moved and slider to match both intensities. This was repeated three times, and the final vibration intensity was set as the average of these adjustments.

3.3.4. EEG Recording

EEG data collection was conducted with the Biosemi ActiveTwo system (Biosemi, Amsterdam, The Netherlands), with 64 active Ag/AgCl electrodes arranged on a nylon cap according to the international 10–10 system. Electrodes were also positioned at the outer corners of both eyes and above and below the left eye, for horizontal (HEOG) and vertical (VEOG) eye movement, respectively. The reference setup was referenced to the Biosemi Common Mode Sense (CMS) and Driven Right Leg (DLR) electrodes. The data was recorded at a 512 Hz sampling rate, filtered online between 0.01 and 100 Hz, and with electrode offsets adjusted to remain under 30 mV prior to recording initiation.

3.3.5. EEG Preprocessing

Preprocessing of EEG data was performed using EEGLAB v2023.0 (Delorme & Makeig, 2004) within MATLAB R2022b. The data was initially resampled to 256 Hz and filtered offline with a band-pass FIR filter ranging from 0.1 to 40 Hz. Epochs were then segmented from –0.8 to 5.3 seconds post-stimulation onset, with baseline correction applied from -200 ms to 0 ms. Artifactual epochs with substantial ocular or muscular interference were manually discarded. Low-quality electrodes were interpolated using spherical spline methods, with a total of 52 electrodes removed across participants (M = 1.53; SD = 1.42 per participant). The average reference was applied to the data, and further noise reduction was achieved through Independent Components Analysis (ICA) with the Extended Infomax algorithm. Eye movements, muscle activity, and other artifact components were identified and removed using the “ICLabel” plug-in in EEGLAB, after which the EEG data was reconstructed.

3.3.6. EEG PSD Analysis

To assess the impact of touch speed on oscillatory amplitude, we calculated the EEG Power Spectral Density (PSD) within the 3-35 Hz frequency range using the EEGLAB "pop_spectopo" function. Data for PSD calculations were taken from a time window spanning 1000 ms to 5000 ms post-stimulus onset to capture a steady-state response while avoiding onset and offset-related activity. The C4 electrode was selected for PSD analysis due to its positioning over the contralateral somatosensory region corresponding to the stimulated arm. Additionally, exploratory analyses were conducted at electrode FCz to examine potential differences in theta oscillations across conditions. Power values from each condition were statistically compared across frequencies using a non-parametric cluster-based permutation test with 10,000 permutations (Maris & Oostenveld, 2007). This method assesses significance by comparing the observed cluster-level statistics (the within-cluster sum of t-values obtained from dependent samples t-tests) to a null distribution obtained through repeated random permutations of the data labels. The sum of the t-values of all data points comprising each cluster (tsum), and the permutation p-value corresponding to each cluster are reported.

3.3.7. EEG Microstate Analysis

The microstate analysis was performed using the EEGLAB toolbox MICROSTATELAB through MATLAB R2022b, following the protocol outlined by Nagabhushan Kalburgi et al. (2023). We performed the following five steps independently on both conditions (stroking and vibration) datasets. First, individual microstate maps were derived by clustering the global field power (GFP) time series, targeting points with optimal signal-to-noise ratios. This clustering was performed with a polarity-independent k-means algorithm (20 repetitions) to group four to seven classes. Next, data quality was assessed by examining variance-explaining maps for each participant; three participants were excluded from further analysis due to artifacts, leaving a final sample of 31 participants, and no outliers were detected. Following this, individual maps were subjected to a second-level clustering to create grand mean maps, which were then organised according to a normative microstate template. We then compared the grand mean microstate maps to a published set (Custo et al., 2017), identifying four reliable microstates based on spatial correlation. These were labelled A, B, C, and D, in line with Koenig et al. (2002). Lastly, a sequence of microstate was derived for each individual's recording, allowing extraction of temporal parameters, including total global variation rate explained, mean duration (stability of each microstate in ms), time coverage (percentage of time occupied by each microstate), and occurrence (frequency of each

microstate per second). A topographical analysis of variance (TANOVA) was conducted using Ragu software to assess differences between microstate classes across conditions.

3.3.8. Statistical Analysis

Statistical analyses were performed using JASP software (version 0.18.3). To analyse the NRS rating values of pleasantness and intensity, two dependent samples *t*-tests were performed, comparing the stroking (average of the 4 speeds) and vibrotactile (average of the 4 durations) stimulations. We conducted Pearson's correlations to explore the relation associations between NRS ratings (pleasantness and intensity, the average of all the scores, aggregating the 4 speeds and the 4 durations) and subscales of the TEAQ. For the electrophysiological indexes, we compared the two conditions (stroking and vibration) using Wilcoxon signed-rank test, both in PSD analysis and to compare the microstate temporal parameters (duration, coverage, and occurrence). Regarding the microstate analysis, after the five steps previously described, we performed a TANOVA to compare the differences between microstate topographies of each microstate class by condition, using the Ragu software in the EEGLAB toolbox MICROSTATELAB through MATLAB R2022b. In addition, to evaluate differences in the microstate topographies and temporal parameters, we computed false discovery rate (FDR) corrections (Benjamini & Hochberg, 1995) using R Studio software.

3.4. Results

The sociodemographic characteristics and TEAQ scores of the sample are presented in Table 7.

Table 7

Sociodemographic Characteristics and TEAQ Scores of the Sample (n = 34)

Variable	Mean	Range
Age, y	22.59 ± 5.19	18-39
Sex, % female	52.94	-
Education, %		
High school	52.90	-
Bachelor's degree	20.60	-
Master	20.60	-
PhD	5.90	-
TEAQ		
FFT	3.66 ± 0.79	2.09-5.00
CIT	3.42 ± 0.91	1.82-4.91
ChT	3.95 ± 0.72	2.50-5.00
ASC	3.14 ± 0.91	1.20-5.00
AIT	4.34 ± 0.55	3.00-5.00
AUT	2.77 ± 0.99	1.20-4.80

Note. SD – standard deviation; y – years; TEAQ – Touch Experiences and Attitudes Questionnaire; FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch.

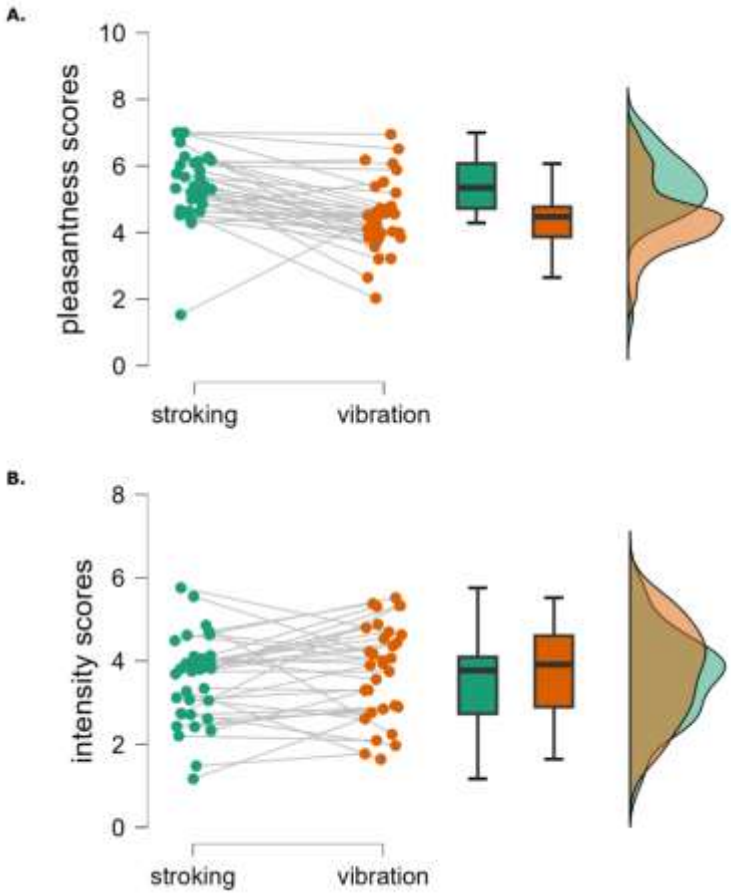
3.4.1. Behavioural Data

For the NRS values regarding self-reported pleasantness, results revealed higher scores for the stroking stimulation (M = 5.37; SD = 1.03) compared to the vibrotactile stimuli (M = 4.48; SD = 1.05), $t(33) = 4.56$, $p < .001$, Cohen's d = .78 (Figure 6A, B). For the NRS values regarding self-reported intensity, results showed no differences in the scores between the stroking stimulation (M = 3.53; SD = 1.05) and the vibrotactile stimuli (M = 3.75; SD = 1.13), $t(33) = -1.22$, $p = .23$, Cohen's $d = .21$. (Figure 6A, B).

Correlations between TEAQ scores and NRS values (pleasantness and intensity) for the stroking and vibration conditions are reported in Table 8. The NRS pleasantness for the stroking condition showed significant positive moderate correlations with the CIT ($r(33) = .47$, $p = .006$, Fisher's $z = .50$), the total TEAQ ($r(33) = .45$, $p = .007$, Fisher's z = .49), and the ChT ($r(33) = .40$, $p = .018$, Fisher's $z = .43$), and a significant positive weak correlation with the AIT ($r(33) = .35$, $p = .046$, Fisher's $z = .36$) scores.

Figure 6

Pleasantness and Intensity Scores for Each Condition (Stroking and Vibration)



Note. A. Individual trends for pleasantness scores; B. Individual trends for intensity scores; Both scores were obtained using a numeric rating scale with values from 1 to 7.

Table 8

Correlation Coefficients Between TEAQ Scores and Pleasantness/Intensity Ratings

	Stroking – Pleasantness		Stroking – Intensity		Vibration – Pleasantness		Vibration – Intensity	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Total score	.45	.007*	- .02	.916	- .007	.968	- .13	.450
FFT	.28	.106	.005	.978	- .13	.461	- .09	.623
CIT	.47	.006*	- .08	.646	.005	.977	- .16	.372
ChT	.40	.018*	.09	.605	.08	.637	.05	.777
ASC	.16	.362	- .05	.759	- .19	.280	- .15	.412
AIT	.35	.046*	- .10	.575	.02	.894	- .25	.150
AUT	.20	.264	.12	.488	.23	.187	.09	.634

Note. FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch; * $p < .05$.

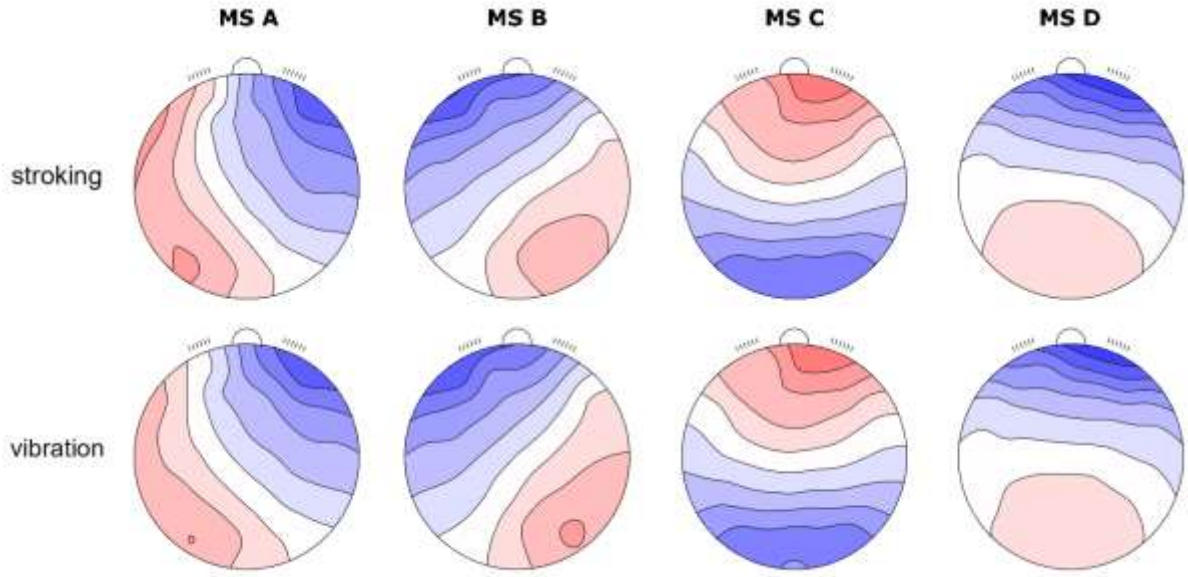
3.4.2. Electrophysiological Data

3.4.2.1. Microstates

3.4.2.1.1. *Microstate Topographies.* Microstate topographies were similar to those reported in the literature (Custo et al., 2017; Koenig et al., 2002) (See Figure 7). The TANOVA results of the individual microstate topographies comparing the two conditions (stroking and vibration) showed no significant differences in any of the four microstate classes.

Figure 7

Mean Microstate Topographies of Both Conditions (Stroking and Vibration)



Note. EEG microstates are polarity invariant since the neuronal generator distribution is the same regardless of the polarity of the map; MS – Microstate.

3.4.2.1.2. Microstate Parameters. The values of the microstate parameters by condition are presented in Table 9. The mean duration was significantly higher in the stroking condition for microstate B ($z(30) = 3.04$, $p_{FDR} = .006$, Rank-Biserial Correlation = .63), and there were no significant differences for microstates A, C and D (Figure 8A). The time coverage of microstates was significantly higher in the vibration condition for microstate A ($z(30) = 4.06$, $p_{FDR} < .001$, Rank-Biserial Correlation = .84), significantly higher in the stroking condition for microstate B ($z(30) = 3.45$, $p_{FDR} = .001$, Rank-Biserial Correlation = .71), and there were no significant differences for microstates C and D (Figure 8B). The frequency of occurrence of microstates was significantly higher in the vibration condition for microstate A ($z(30) = 4.23$, $p_{FDR} < .001$, Rank-Biserial Correlation = .87), significantly higher in the stroking condition for microstate D ($z(30) = 2.41$, $p_{FDR} = .033$, Rank-Biserial Correlation = .50), and there were no significant results for microstates B and C (Figure 8C).

Table 9

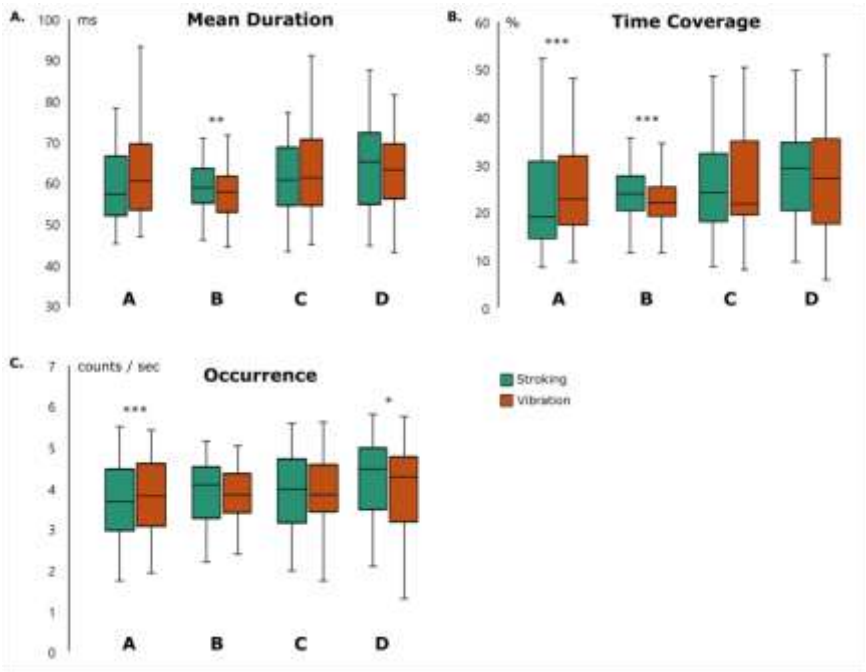
Microstate Parameter Values by Condition

	Stroking	Vibration
GEV (%)	61.09 ± 9.93	61.08 ± 10.53
Mean duration (ms)	64.60 ± 5.85	64.85 ± 6.08
Mean occurrence (Hz)	15.60 ± 1.35	15.55 ± 1.39
Microstate A		
Duration (ms)	60.55 ± 11.24	62.56 ± 12.98
Occurrence (Hz)	3.60 ± 1.04	3.84 ± 1.00
Coverage (%)	22.64 ± 10.00	24.90 ± 10.80
Microstate B		
Duration (ms)	59.78 ± 6.86	57.92 ± 6.74
Occurrence (Hz)	3.87 ± 0.77	3.79 ± 0.73
Coverage (%)	23.46 ± 5.99	22.31 ± 5.88
Microstate C		
Duration (ms)	64.58 ± 14.59	65.49 ± 15.87
Occurrence (Hz)	3.92 ± 0.83	3.92 ± 0.86
Coverage (%)	25.96 ± 9.64	26.44 ± 10.52
Microstate D		
Duration (ms)	64.65 ± 12.42	63.60 ± 12.90
Occurrence (Hz)	4.21 ± 1.01	4.00 ± 1.17
Coverage (%)	27.95 ± 10.03	26.35 ± 10.84

Note. GEV – global explained variance; ms – milliseconds; Hz – Hertz.

Figure 8

Within-Subjects Comparison of the Microstate Parameters by Condition (Stroking and Vibration)

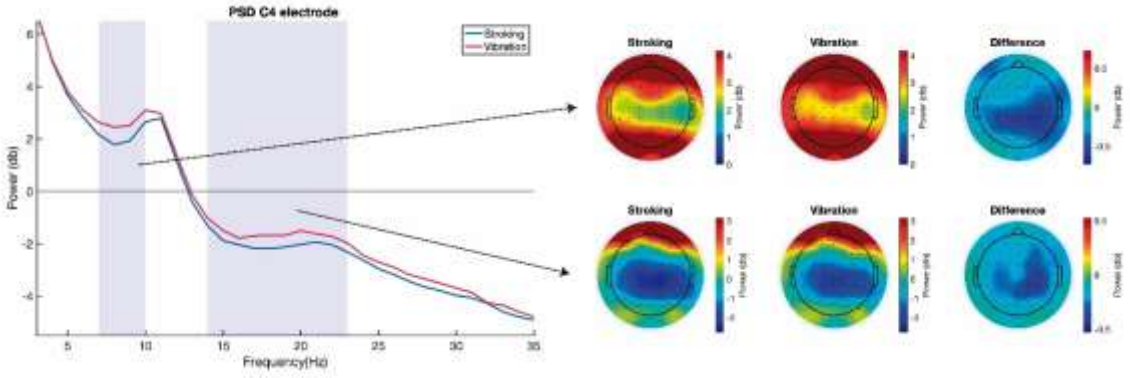


Note. * $p < .05$; ** $p < .01$; *** $p < .001$, with FDR correction.

3.4.2.2. Power Spectral Density. Regarding PSD, cluster-based permutation test over the contralateral somatosensory area (C4) revealed a significant cluster in the lower alpha range (from 7 Hz to 10 Hz) with more reduced power for the stroking condition (M = 2.13; SD = 4.36) than for the vibration condition (M = 2.67; SD = 4.46) ($t$sum = -13.7, p = .040), and a second significant cluster in the beta band (from 14 Hz to 23 Hz) with also more reduced power for the stroking condition (M = -2.01; SD = 4.94) than for the vibration condition (M = -1.62; SD = 4.89) ($t$sum = -29.9, p = .003) (See Figure 9). We also analysed PSD over fronto-central locations (FCz) to explore differences in theta oscillations. In this electrode, a significant cluster was found in the lower alpha range (from 7 Hz to 9 Hz) with reduced power for the stroking condition ($t$sum = -8.5, p = .042), but no differences were observed at lower frequencies.

Figure 9

Power Spectral Density (PSD) of the C4 Electrode



Note. Shaded rectangles indicate the frequency windows with significant clusters (from 7 Hz to 10 Hz and from 14 Hz to 23 Hz). The right side shows the topographic maps of the power values in each condition (stroking and vibration) and the differences (stroking minus vibration).

3.5. Discussion

Our study aimed to shed light on the brain oscillatory dynamics and spatial field distributions of touch mediated by CT afferents, comparing these with those of discriminative touch. To accomplish this, we compared the brain's electrical activity and microstates evoked by affective touch, stimulating CT fibres through soft brush stroking at CT-optimal speeds, with those elicited by discriminative touch, using vibrotactile stimulation via a linear resonant actuator at approximately 200 Hz, both matched for perceived intensity. The behavioural results demonstrated higher pleasantness ratings for stroking compared to vibrotactile stimuli, with no significant differences in intensity ratings. Stroking pleasantness positively correlated with the Touch Experiences and Attitudes Questionnaire (TEAQ) total score, as well as the Childhood Touch, Current Intimate Touch, and Attitude to Intimate Touch subscales. The power spectral density analysis revealed reduced power for stroking stimuli, in the alpha/mu and beta bands in

central/Rolandic areas. Additionally, compared to vibration, the stroking condition revealed a reduced prevalence of microstate A (in time coverage and occurrence), together with an increased prevalence of microstate B (in mean duration and occurrence) and D (in occurrence). While the findings in oscillatory dynamics replicate prior results showing alpha/mu and beta desynchronisation during affective touch (Case et al., 2016; Gazzola et al., 2012; Schirmer et al., 2022), the microstate analysis provides a novel perspective on the modulation of this type of touch in EEG topographies related to attentional and arousal processes.

Stroking received significantly higher pleasantness ratings compared to the vibrotactile condition, aligning with prior findings emphasising the emotional significance of CT-mediated touch (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2008, 2002; Walker et al., 2022). Furthermore, stroking pleasantness was also correlated with the total score of the TEAQ. Considering that a higher total score in TEAQ indicates a more positive attitude toward touch and more frequent touch experiences (Trotter et al., 2018), this result suggests that hedonic evaluation of neutral stimulation of CT fibres with a brush is related to overall experiences and attitudes toward social affective touch. Regarding the TEAQ subscales, stroking pleasantness was correlated with current experiences of intimate touch (CIT) and attitude to intimate touch (AIT), suggesting that, despite the absence of a social component in the touch administered by the robot, individuals who find CT fiber stimulation more pleasant also report more interactions and comforting touch in intimate relationships. These findings align with previous observations showing AIT as a predictor of pleasantness ratings for both robotic and vicarious touch (Ali et al., 2023). Together, they highlight how the closeness of intimate relationships, and the emotional dynamics within them, influence the perceived pleasantness and comfort derived from touch (Suvilehto et al., 2015). In addition, a significant correlation with the childhood touch (ChT) subscale was also observed, proposing that early positive touch experiences may also shape the valence of CT stimulation in adulthood. This is in agreement with studies indicating that nurturing physical interactions during childhood can foster positive emotional responses to touch later in life, reinforcing the notion that early touch experiences significantly influence adult perceptions of tactile stimulation (Field, 2010). In contrast, no significant correlations were found between stroking pleasantness and the subscales related to attitude to self-care (ASC), attitude to unfamiliar touch (AUT), and touch experiences with friends and family (FFT). No correlations were found between vibration pleasantness and any of the TEAQ subscales. This finding indicates that touch experiences and attitudes are only related to pleasantness during stroking and do not extend to discriminative touch, supporting the emotional role of CT touch (McGlone et al., 2007, 2014; Morrison et al., 2010). Furthermore, no significant differences were observed in intensity ratings, ensuring a

controlled comparison between conditions. In the same vein, the intensity of both stroking and vibration did not correlate with any TEAQ measure. In conclusion, the correlations between brushing pleasantness and the scores obtained in the touch experiences and attitudes questionnaire support the idea that our experience with touch, particularly in intimate contexts, shapes the perception of touch, even in the absence of a social stimulus.

In the microstate analysis, microstate A showed shorter time coverage and occurrence for stroking. Microstate A is associated with networks involved in arousal regulation (Custo et al., 2017; Schiller et al., 2023; Tarailis et al., 2024). CT-targeted touch has been documented to decrease arousal levels (Walker et al., 2022). A reduction in arousal has also been observed during hand-holding with an intimate person or even a stranger (Coan et al., 2006), as well as when caregivers stroke children (Fotopoulou et al., 2022). The reduction of coverage and occurrence of Microstate A may be a correlate of decreased arousal during CT stimulation. In contrast, Microstate B showed an increase in the mean duration and occurrence during stroking. Microstate B is related to visual-spatial attention (Tarailis et al., 2024; Zappasodi et al., 2019). Increased duration and occurrence of this microstate could be a correlate of the heightened attention engagement during CT stimulation. This result could be potentially linked to the dynamic nature of the stroking stimulus compared to the static nature of vibration. Similarly, the increased occurrence of microstate D, associated with attention-related processing and executive functioning (Custo et al., 2017; Schiller et al., 2023), further emphasises the prioritisation of attentional resources during affective touch. These findings could be a correlate of the CT-mediated calming effects that guide social and affective interactions (Croy et al., 2022).

Consistently with our hypothesis, which predicted power suppression of alpha/mu over somatosensory cortical locations in the CT condition, we found significantly lower alpha/mu power in central/Rolandic regions during the stroking condition compared to the vibration condition. The reduction in the power of alpha oscillations is related to heightened attentional capture (Klimesch et al., 2007; Sauseng et al., 2005) and an increase in the perception stimulus properties (Griffiths et al., 2019). However, as the stroking stimulus is dynamic, and the vibration is static, some of the differences in alpha/mu desynchronisation may also reflect these differences in stimulus dynamics rather than touch type alone. As with Microstate D results, reduced alpha/mu power indicates that CT activation involves more processing resources and greater activation over somatosensory areas. This suggests that affective touch requires additional neural resources that may be crucial for guiding social interactions and associated emotional responses. Our results align with those of Singh et al. (2014), who also found alpha band desynchronisation in the somatosensory cortex for tactile stimulation on the forearm. Moreover, von

Mohr et al. (2018) found alpha reduction during brushing administered on the forearm by a researcher (at both CT-optimal and CT-non-optimal speeds) compared to a no-touch condition, but no differences in alpha power for CT-optimal vs the CT-non-optimal speed. Our results expand this observation and suggest that CT-touch is related to higher alpha desynchronization also when compared to discriminative touch.

The beta band power was also reduced in central/Rolandic areas for the stroking condition compared to the vibration condition. Rolandic beta oscillations are closely associated with sensorimotor integration, motor control, and execution (Pfurtscheller & Lopes da Silva, 1999). Increased beta power is often associated with a more inhibited or 'idling' state of the sensorimotor cortex, preventing unnecessary movements (Muralidharan et al., 2019). Conversely, beta desynchronisation indicates a release of inhibition, facilitating motor planning and execution (Kilavik et al., 2013). Similar to the alpha band, our results are in line with those found by Singh et al. (2014) and von Mohr (2018), where beta suppression was observed for tactile stimuli on the forearm. These findings show that the brain dynamically adjusts its oscillatory activity depending on the nature of the tactile stimulus. CT-mediated touch appears to elicit a unique neural signature characterised by desynchronisation in the alpha/mu and beta bands, suggesting an enhanced engagement of sensorimotor circuits and higher cortical excitability than the discriminative dimension of touch.

Some limitations need to be considered in this study. CT stimulation was performed using a robot with a soft brush, although this technique is widely used to activate these fibres, reducing potential variability introduced by human error and avoiding interpersonal factors, actual human touch could provide a more naturalistic approach. Additionally, participants primarily consisted of young adults (average age below 30), which may limit the generalisation of the findings to older people. Also, the stroking speeds used here were all CT-optimal velocities, comparing CT-optimal with non-optimal speeds could have provided additional insights into the neural correlates of CT activation. Furthermore, while the four stroking velocities were selected to introduce variation and prevent identical perceptions, we did not collect explicit behavioural data confirming whether participants consciously perceived them as distinct speeds. Another limitation is the difference between the dynamic nature of the stroking stimulus and the static nature (i.e., applied to the same region of the skin) of the vibrotactile stimulus. Although we cannot determine to what extent this difference may contribute to the observed effects in PSD and microstates, including conditions that control for stimulus dynamics, such as dynamic vibrotactile stimulation could help to disentangle further specific contributions of CT-optimal touch and vibrotactile stimulation to the neural correlates. Future research should also address the psychophysiological indexes of CT activation

in populations with conditions such as autism spectrum disorder or chronic pain, where disruptions in affective touch processing have been observed.

To conclude, our results demonstrated power desynchronisation in the alpha/mu and beta bands in central/Rolandic areas during CT stimulation. This desynchronisation suggests increased sensorimotor cortical excitability, highlighting the unique neural signatures associated with affective touch and engaging specific cognitive and sensory processes differently than discriminative touch. Additionally, microstate analysis suggests that stroking can engage increased attentional resources compared to discriminative touch, indicating a prioritisation of this type of information. Overall, this study brought knowledge about the preferential processing of affective touch-related information and its distinct neural signature.

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CHAPTER 4

Neurophysiological Responses to Vicarious Affective Touch: An Electroencephalography (EEG) Study

Chapter 4. Neurophysiological Responses to Vicarious Affective Touch: An Electroencephalography (EEG) Study

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Supplementary material can be found in Appendix B.

4.1. Abstract

Affective touch is a somatosensory modality involved in forming and consolidating rewarding social interactions and hypothesised to be encoded by a population of cutaneous unmyelinated low threshold mechanosensory C-Tactile afferents (CT). CTs are preferentially activated by a caressing type of touch delivered at speeds around 3 cm/s (CT-optimal speed) and at skin temperature. Given its social relevance, the vicarious observation of affective touch can cause high empathic resonance in the observer. However, little is known whether the observation of CT-optimal touch is processed differently in the observer's brain than at other CT-suboptimal speeds. In our study, we evaluated subjective reports of the pleasantness/willingness of observers to receive such touch whilst recording the electroencephalogram (EEG) as they watched touch videos at three different speeds: static, slow (CT-optimal), and fast touch. We found that CT-optimal touch was rated as more pleasant and elicited greater willingness to engage, compared to static or fast touch. CT-optimal touch also led to significantly lower beta power, reflecting greater EEG desynchronisation, compared to the other conditions. Other frequency bands, such as theta and alpha, showed increased modulation to slow and fast touch compared to static touch. However, no differences were found between slow and fast conditions in the alpha and theta bands. Our results suggest that vicarious processing of affective touch at the optimal speed for CT receptors involves broader neural resources and higher activation of somatosensory areas, highlighting the significance of this touch modality in sensory processing.

4.2. Introduction

The sense of touch enables us to discern different discriminative tactile sensations as well as the emotional aspects of physical contact (McGlone et al., 2007, 2014; Morrison et al., 2010; Morrison, 2016). This affective dimension of touch is crucial throughout our lifespan, supporting our social relationships and well-being (Cascio et al., 2019; Morrison et al., 2010; Olausson et al., 2016; Walker & McGlone, 2013).

Using the technique of microneurography, Swedish researchers have identified and characterised a population of cutaneous afferent nerves in skin of humans that respond preferentially to a caressing touch and are hypothesised to be the neural substrate responsible for the pleasant – affective – qualities of touch (Nordin, 1990; Vallbo et al., 1993, 1999). These nerves, called C-Tactile afferents (CT), are unmyelinated low-threshold mechanoreceptors that innervate the hairy skin of the body and respond optimally to gentle, caress-like stroking (Olausson et al., 2010; Vallbo et al., 1993), at slow speeds (1-10 cm/s) and body temperature (Ackerley et al., 2014; Löken et al., 2009). CT-optimal speeds are also reported as more pleasant than slower and faster stroking (Ackerley et al., 2014; Essick et al., 1999, 2010; Löken et al., 2009).

Research suggests a mirror-like response to vicarious touch, where brain regions activated during felt touch are similarly engaged in observed touch (Bolognini et al., 2014; Keysers et al., 2004, 2010; McCabe et al, 2008; Morrison et al., 2011; Schaefer et al., 2005, 2009, 2012). These findings highlight the involvement of complex neural mechanisms and individual factors in vicarious touch processing, particularly the role of somatosensory and empathy-related areas, such as the posterior insular cortex (Bufalari & Ionta, 2013; Ebisch et al., 2011; Lee Masson et al., 2018; Morrison et al., 2011). Notably, vicarious touch perception exhibits significant variability across populations (Gillmeister et al., 2017) and is modulated by factors such as visual perspective and body ownership, which influence neural and emotional responses to observed touch (Lisi et al., 2024). Observing this type of touch is often perceived as more pleasant, highlighting its social and emotional significance (Devine et al., 2020; Haggarty et al., 2021a, 2021b; Morrison et al., 2011; Walker et al., 2017).

Electrophysiological studies on physical touch found that CT-optimal and non-CT-optimal touch speeds reduce alpha and beta brain oscillation, with theta and beta activity specifically reduced at CT-optimal speeds (Von Mohr et al., 2018). Other studies on tactile processing, including both affective and discriminative touch, indicate a similar suppression of these bands recorded over somatosensory areas (Michail et al., 2016; Singh et al., 2014). Specifically, alpha suppression is more prominent in parieto-occipital regions, while theta and beta suppression occur in frontal and vertex areas (Michail et al., 2016).

Using event-related potentials (ERPs), Schirmer et al. (2022) found a larger negativity in the N400 component for CT-optimal speeds compared to non-optimal speeds, while Varlamov et al. (2022) found a higher ERP amplitude at around 400–1800 ms for fast stroking, and a P2100–N2300 complex accompanied by an ultra-late positive potential (LPP) for slow stroking.

The literature on vicarious affective touch remains scarce, but evidence suggests that observing images of social touch induces greater mu-suppression (oscillations in the alpha band [≈ 10 Hz] observed at central sites and related to sensorimotor activation) compared to no-touch or non-social touch (Peled-Avron et al., 2016). Alpha activity is prominent across various sensory areas, particularly in the visual cortex, and its desynchronisation reflects the brain's prioritisation of relevant sensory input (Van Diepen et al., 2019). Schirmer and McGlone (2019) found that drawings of affectionate touch led to increased power in both alpha and beta bands compared to no-touch drawings. They also found a larger LPP in centro-parietal areas for touch images, especially when processed explicitly. This ERP component, typically observed over central-parietal areas (Liu et al., 2012; Zhu et al., 2015), is known to be influenced by both attention and emotional relevance (Nowparast Rostami et al., 2016; Pollux, 2016).

Beta and theta rhythms are also relevant in processing touch-related visual information. Beta rhythm, predominantly modulated over the motor and somatosensory cortices, desynchronises during movement and shows a post-movement rebound (Nam et al., 2011; Pfurtscheller et al., 2006; Stavrinou et al., 2007). These oscillations are modulated by actual and imagined movement as well as action observation (Brunsdon et al., 2019; Galdo-Alvarez et al., 2016). Additionally, beta suppression has been linked to somatosensory and motor processes, particularly in response to affective and social stimuli. This phenomenon is thought to reflect the brain's engagement with emotionally salient information, involving both sensory and attentional components (Charidza & Gillmeister, 2022). Theta activity, prominent over mid-frontal regions, increases during tasks requiring heightened attention or cognitive control (Cavanagh & Frank, 2014) and is sensitive to the emotional content of stimuli (Pidal-Miranda et al., 2019; Sammler et al., 2007). It also plays a significant role in attentional processes related to somatosensory input (Shen et al., 2019; Zhang et al., 2019). Therefore, exploring beta and theta bands, alongside alpha and LPP, is essential in studying vicarious affective touch.

In this study, we aimed to explore psychophysical ratings and electroencephalogram (EEG) during the observation of different types of touch in healthy adults. Unlike previous studies that relied on static images, we used dynamic videos to assess the role of touch speed, a crucial factor that shapes its affectivity. Our aims were twofold: to evaluate differences in valence during the observation of static, CT-optimal, and fast touch, and to characterise the underlying electrophysiological correlates (i.e., ERPs,

power spectral density (PSD), and time-frequency data). We hypothesised that CT-optimal speed would be rated as more pleasant than suboptimal speeds (static and fast touch). We also expected the LPP ERP component to show increased amplitude in parietal regions for CT-optimal when compared with suboptimal speeds, reflecting the allocation of more attentional resources to this affective stimulus. For neural oscillations, we predicted that CT-optimal speed, compared with suboptimal speeds, would be related to higher mid-frontal theta power, reflecting emotional engagement and attentional capture; reduced alpha/mu activity in Rolandic and visual regions, given previous findings of alpha suppression during tactile stimulation; and decreased beta activity in central regions, aligning with previous research showing beta suppression in tactile stimulation processing over central areas.

4.3. Materials & Methods

4.3.1. Participants

Participants were 30 healthy young adults (15 females; one male participant had to be eliminated due to the low quality of the EEG, making a total of 29 participants in the EEG analysis) with ages between 18 and 28 years (M = 21.40; SD = 2.72). All of them reported normal or corrected vision. Exclusion criteria were the presence of head injury or other current neurological or psychiatric conditions. Additional sample characteristics are detailed in Table 10. Participants were recruited through a credit system at the University of Minho and received credits for their participation. All participants provided written informed consent, and the study protocol was in accordance with the Declaration of Helsinki. The research protocol obtained approval from the ethics committee for Research in Health and Life Sciences at the University of Minho (CEICSH 023/2020).

Table 10

Socio-Demographic Characteristics and TEAQ Scores of the Sample (n = 30)

Variable	Mean (SD)	Range
Age, y	21.40 (2.72)	18-28
Sex, % female	50	-
Education, %		
High school	53.3	-
Bachelor's Degree	23.3	-
Master	23.3	-
TEAQ		
FFT	3.60 (0.95)	1.27-5.00
CIT	3.49 (0.76)	1.82-4.91
ChT	3.77 (0.92)	1.75-5.00
ASC	3.31 (0.88)	1.40-4-80
AIT	4.43 (0.48)	3.25-5.00
AUT	2.85 (1.00)	1.20-4.60

Note. SD – standard deviation; y – years; TEAQ – Touch Experiences and Attitudes Questionnaire; FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch.

4.3.2. Procedure and Psychosocial Assessment

Initially, participants filled out a socio-demographic questionnaire and a checklist to ensure their suitability for EEG recording. They also completed the Portuguese version of the Touch Experiences and Attitudes Questionnaire (TEAQ) (Pereira et al., 2023). This questionnaire evaluates touch experiences both currently and during childhood, as well as attitudes toward touch. The Portuguese TEAQ comprises 52 items divided into six subscales: Friends and Family Touch (FFT), relating to interpersonal touch experiences with friends and family; Current Intimate Touch (CIT), determines current levels of intimate touch experiences between people who are emotionally close or in a romantic relationship; Childhood Touch (ChT), provides a measure of positive childhood touch experiences; Attitude to Self-Care (ASC), related to skincare and grooming behaviours associated with positive self-care; Attitude to Intimate Touch (AIT), referring to attitudes towards touch experiences between people who are emotionally close or in a romantic relationship; and Attitude to Unfamiliar Touch (AUT), that relates to attitudes to touch experiences with someone that the individual is less close to, or even a stranger. Participants rated each item on a 5-point Likert scale, ranging from 1 ('Disagree strongly') to 5 ('Agree strongly'). Subscale scores were calculated as the mean of the items belonging to each of them, with a higher score indicating a more positive attitude toward touch or more frequent touch experiences. After that, participants were fitted with an EEG recording cap and seated in a soundproofed room, positioned one metre from the computer screen. Following these preparations, they began the experimental task.

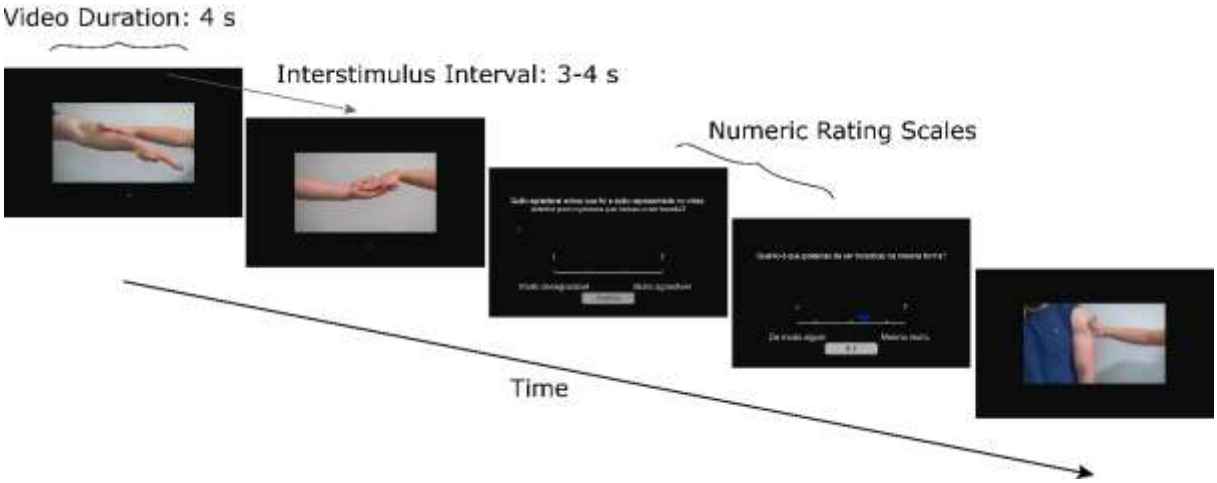
Finally, to further investigate the independent influence of stimulus speed, we conducted an exploratory follow-up study employing a simplified paradigm with videos showing dots at different speeds (see Appendix B).

4.3.3. Experimental Task

The task consisted of watching a set of 15 short videos (4 s each) depicting an actor being touched by another person at five different skin sites (back, upper arm, ventral forearm, dorsal forearm, and palm), and at three different speeds (static, 3 cm/s - CT-optimal speed, and 30 cm/s - fast non-CT-optimal speed - from now these terms will be used to describe the three velocities). The videos, identical to those used in previous studies by Walker et al. (2017), Devine et al., (2020), and Haggarty et al. (2021a, 2021b), do not include any social context and features touch only on body areas that are rated positively in social contexts. While the original videos were 6 seconds long, we trimmed the first and last seconds to create 4-second videos, starting with the movement already in progress and maintaining a constant speed throughout. Each of the 15 videos was shown 10 times in a random order for each participant. Throughout the task and randomly, the participants were asked to rate each video twice (i.e., each one of the 15 videos was only assessed twice), using a numeric rating scale from 1 ('Not at all') to 7 ('Extremely'), with one decimal place. The two questions were "How pleasant do you think that action was for the person being touched?" (hereafter referred to as "Other") and "How much would you like to be touched like that?" (referred as "Self"). The order of the questions was fixed and consecutively. As in Haggarty et al. (2021a), both questions were asked in order to distinguish between perceptions of touch for others versus oneself, which may be useful for future research on populations with impaired empathic abilities. Participants were instructed that they would watch videos of social interactions and that they would have to answer the two specified questions. See Figure 10 for a visual representation of the task.

Figure 10

Timeline of the Task



Note. The 4-s videos only showed the forearm of one person touching another (at five different body locations and three different speeds). The interstimulus interval had a random duration from 3 to 4 s. Of the 10 times that each video was presented, in two of them, the participants had to evaluate how pleasant it was for the person being touched and how pleasant that touch would be for them (using the computer mouse; on a scale from 1 to 7 with one decimal value).

4.3.4. EEG Recording

Electroencephalogram (EEG) was recorded using a Biosemi ActiveTwo system (Biosemi, Amsterdam, The Netherlands) from 64 active Ag/AgCl scalp electrodes placed on a nylon cap. Electrode locations were arranged according to the international standard 10–10 system. Five additional active electrodes were placed in the lateral canthi of both eyes (horizontal electrooculogram–HEOG), above and below the left eye (vertical electrooculogram–VEOG), and at the tip of the nose. Electrodes were referenced to the Common Mode Sense (CMS) and Driven Right Leg (DLR) Biosemi electrodes. The EEG was recorded at a sampling rate of 512 Hz and on-line filtered between 0.01 and 100 Hz. Electrode offsets were below 30 mV before starting the recording.

4.3.5. EEG Analysis

The EEG was pre-processed using EEGlab v2021.1 software (Delorme & Makeig, 2004) running on MATLAB R2021b. It was first resampled to 256 Hz and offline filtered using a band-pass FIR filter from 0.1 to 40 Hz. The EEG was then segmented into epochs from -2 to 5 seconds after the presentation of the videos. Baseline correction from -200 ms to 0 ms was applied. Epochs showing major muscular or other artifacts were manually removed. In addition, a total of 39 electrodes were eliminated due to poor recording quality (pooling all participants; making an average of about 1.3 electrodes removed per participant) and reconstructed using spherical splines interpolation. The trials per condition after data

cleaning were: static condition – *M* = 46.8, *SD* = 3.5, range = 37-50 epochs; CT-optimal speed condition – *M* = 46.7, *SD* = 3.7, range = 36-50 epochs; fast condition – *M* = 46.8, *SD* = 3.3, range = 38-50 epochs. The EEG was re-referenced to the average reference. For further noise removal, Independent Component Analysis (ICA) was applied using Extended Infomax ICA. Components representing eye artifacts, muscular artifacts, and loose electrodes were rejected and the EEG was reconstructed. The classification and selection of the components for removal were carried out with the assistance of the EEGLab plug-in "ICLabel". To evaluate how touching speed modulates the amplitude of oscillations we first computed the Power Spectral Density (PSD) of the EEG for each electrode from 0 to 40 Hz and (using the EEG in a window from 300 ms after the beginning of the video to 3700 ms; this time window was selected to use the data with the video already started and shortly before its end to avoid onset and offset evoked activity that is independent of the stimulus speed). The mean power values of the three frequency bands of interest; theta (3-6 Hz), alpha (9-12 Hz), and beta (16-22 Hz) were used for statistical analyses. These analyses were performed on the mean PSD values of all the electrodes in the scalp allowing us to have a global view of the electrophysiological changes induced by stimuli of longer duration, as is the case of the videos in this work. Subsequently, in those frequency bands where significant differences were found, we evaluated the topographical differences between the conditions by performing a cluster-based permutation test.

For further ERP and time-frequency analysis, we applied a current source density transformation based on spherical spline surface Laplacian (with splines of m = 4; smoothing constant = 10^{-5}), using the MATLAB code provided by Kayser and Tenke (2006). This type of filter removes spatially broad features of the data while leaving local features unmodified, allowing for a more spatially detailed analysis. The LPP ERP component was measured at centroparietal locations (the Cz, CPz, and Pz electrodes) commonly used in the literature and in the time window in which it showed its greatest modulation after visual inspection (from 350 ms to 600 ms). Time-frequency analysis was performed by convolving the EEG data with a family of complex Morlet wavelets ranging in frequency from 2 Hz to 40 Hz in 35 logarithmically increasing steps, and with logarithmically increasing cycles, from 3 cycles at the lowest frequency to 8 at the highest frequency. Power data obtained after convolution was baseline corrected by transforming the power change of each time-frequency pixel to dB, relative to the mean power in the baseline (using an interval from −300 ms to −200 ms) of each frequency. Again, we measured the power values of theta, alpha, and beta bands for further analyses. Theta power was measured in Fz electrode, as it was the frontocentral location in which modulation was greatest regardless of condition differences (Cohen & van Gaal, 2013). Alpha power was measured in PO7/PO8 for visual-related activity as it showed

greater modulation, and in Cz for Rolandic mu activity. Beta power was measured in Cz, since this is the electrode where such activity is commonly observed (McFarland et al., 2000). The frequency bands selected for time-frequency analysis were the same as those used for the PSD analysis. Since there is no clear consensus on which are the limits of each frequency band, in this work we selected theta and alpha limits for showing its maximum modulation in the average of the 3 conditions. This could not be done in the beta range, since there was no clear modulation after visual inspection, we limited this frequency band to the most central frequencies of this range (16-22 Hz). These specific limits for somatosensory beta had been used in previous studies (Neuper et al., 2005; Pfurtscheller et al., 1997).

4.3.6. Statistical Analysis

Repeated measures ANOVAs with the speed of stroking (static, slow, fast) and body location (palm, dorsal forearm, ventral forearm, upper arm, back) as within-subject factors were applied to evaluate participants' ratings. For the electrophysiological indices, since these require a larger number of trials to have a good signal-to-noise ratio, we only compared the speed factor using a one-way repeated measures ANOVA. The Greenhouse-Geisser correction was applied when the assumption of sphericity was violated. Post-hoc paired comparisons were computed with Holm correction. Measures of effect size (Eta squared, η_p^2, and Cohen's *d*) are reported. We also explored the relationship between touch experiences and attitudes (measured by the different subscales of the TEAQ) and participants' ratings (the average of all the scores, aggregating the 3 speeds and the 5 locations) using Pearson correlations. The statistical analyses were performed using the JASP software (version 0.15).

In addition, to evaluate the topographical differences in PSD, we computed the paired comparisons between conditions using cluster-based permutation tests with the FieldTrip function "ft_timelockstatistics" (Monte Carlo method with 10000 permutations and alpha level = 0.05) (Oostenveld et al., 2011). Clusters of neighbour electrodes with significant differences are shown in Figure 12.

4.4. Results

4.4.1. Behavioural Data Analysis

The mean rates for each question are presented in Table 11.

For the question values after the question "*How pleasant do you think that action was for the person being touched?*", repeated measures ANOVA results revealed a significant main effect of speed [$F(2,58) = 22.92$, $p < .001$, $\eta_p^2 = .44$]. Post-hoc paired comparisons showed significant differences

between the conditions slow vs static [$t(28) = 6.32$, $p < .001$, Cohen's $d = 1.13$] and slow vs fast [$t(28) = 5.26$, $p < .001$, Cohen's $d = .94$], with higher ratings for the slow condition. No significant differences were observed for the condition's static vs fast [$t(28) = 1.06$, $p = .293$, Cohen's $d = .19$]. There was also a significant main effect of skin location [$F(2.4,68.9) = 3.30$, $p = .035$, $\eta_p^2 = .10$], with post-hoc comparisons showing significant differences between the back and the dorsal forearm [$t(28) = 3.38$, $p = .01$, Cohen's d = .61], with higher ratings for the back. No significant differences were observed for the other conditions (palm vs ventral forearm: $t(28) = 0.03$, $p = 1.00$, Cohen's $d = .006$; palm vs dorsal forearm: $t(28) = 1.76$, $p = .65$, Cohen's $d = .32$; palm vs upper arm: $t(28) = 1.11$, $p = 1.00$, Cohen's $d = .20$; palm vs back: $t(28) = 1.62$, $p = .65$, Cohen's $d = .29$; ventral forearm vs dorsal forearm: $t(28) = 1.73$, $p = .65$, Cohen's $d = .31$; ventral forearm vs upper arm: $t(28) = 1.07$, $p = 1.00$, Cohen's $d = .19$; ventral forearm vs back: $t(28) = 1.65$, $p = .65$, Cohen's $d = .30$; dorsal forearm vs upper arm: $t(28) = 0.66$, $p = 1.00$, Cohen's $d = .12$; upper arm vs back: $t(28) = 2.72$, $p = .07$, Cohen's $d = .49$). A significant interaction effect between speed and skin location [$F(8,232) = 5.78$, $p < .001$, $\eta_p^2 = .03$] also emerged. This effect revealed that participants rated the touch on the palm as more pleasant than the touch on the dorsal forearm [$t(28) = 4.39$, $p = .002$, Cohen's $d = .80$] and on the upper arm [$t(28) = 4.36$, $p = .002$, Cohen's $d = .79$], for the static condition. For all skin locations, participants rated the slow touch as more pleasant than the fast touch, except for the back (palm: $t(28) = 4.55$, $p = .001$, Cohen's $d = .82$; dorsal forearm: $t(28) = 4.00$, $p = .008$, Cohen's $d = .72$; ventral forearm: $t(28) = 3.86$, $p = .01$, Cohen's $d = .70$; upper arm: $t(28) = 4.54$, $p = .001$, Cohen's $d = .82$; back: $t(28) = 3.34$, $p = .08$, Cohen's $d = .60$), and the same happened comparatively to the static condition, except for the palm (palm: $t(28) = 1.76$, $p = 1.00$, Cohen's $d = .32$; dorsal forearm: $t(28) = 5.94$, $p < .001$, Cohen's $d = 1.07$; ventral forearm: $t(28) = 4.34$, $p = .002$, Cohen's $d = .78$; upper arm: $t(28) = 6.96$, $p < .001$, Cohen's $d = 1.26$; back: $t(28) = 5.37$, $p < .001$, Cohen's $d = .97$) (see Figure 11A).

For the question values after the question "*How much would you like to be touched like that?"*, repeated measures ANOVA also revealed a significant main effect of speed [$F(2,58) = 26.87$, $p < .001$, $\eta_p^2 = .48$]. Post-hoc comparisons showed a significant effect for the conditions slow vs static [$t(28) = 6.73$, $p < .001$, Cohen's $d = 1.08$] and slow vs fast [$t(28) = 5.88$, $p < .001$, Cohen's $d = .94$], with higher ratings for the slow condition. No significant differences were observed for the conditions static vs fast [$t(28) = 0.86$, $p = .40$, Cohen's $d = .14$]. There was also a significant main effect of skin location [$F(2.3,66) = 3.09$, $p = .046$, $\eta_p^2 = .10$], with significant differences between the back and the dorsal forearm [$t(28) = 3.13$, $p = .022$, Cohen's $d = 0.53$] and the back and the upper arm [$t(28) = 2.91$, $p = .039$, Cohen's $d = .36$], with higher ratings for the back. No significant differences were observed for the

other conditions (palm vs ventral forearm: $t(28) = 0.34$, $p = 1.00$, Cohen's $d = .06$.; palm vs dorsal forearm: $t(28) = 1.32$, $p = 1.00$, Cohen's $d = .22$; palm vs upper arm: $t(28) = 1.09$, $p = 1.00$, Cohen's $d = .19$; palm vs back: $t(28) = 1.82$, $p = .50$, Cohen's $d = .31$; ventral forearm vs dorsal forearm: $t(28) = 0.98$, $p = 1.00$, Cohen's $d = .17$; ventral forearm vs upper arm: $t(28) = 0.75$, $p = 1.00$, Cohen's $d = .13$; ventral forearm vs back: $t(28) = 2.16$, $p = .27$, Cohen's $d = .36$; dorsal forearm vs upper arm: $t(28) = 0.22$, $p = 1.00$, Cohen's $d = .04$). A significant interaction effect between speed and skin location [$F(8,232) = 5.30$, $p < .001$, $\eta_p^2 = .03$] was observed. This effect revealed that participants rated the touch on the palm as more pleasant than the touch on the dorsal forearm [$t(28) = 4.01$, $p = .006$, Cohen's $d = .70$] and on the upper arm [$t(28) = 4.05$, $p = .006$, Cohen's $d = .71$], for the static condition. For all skin locations, participants rated themselves as more willing to receive the slow touch than the fast touch (palm: $t(28) = 4.25$, $p = .003$, Cohen's $d = .72$; dorsal forearm: $t(28) = 4.81$, $p < .001$, Cohen's $d = .82$; ventral forearm: $t(28) = 4.06$, $p = .006$, Cohen's $d = .69$; upper arm: $t(28) = 4.92$, $p < .001$, Cohen's $d = .84$; back: $t(28) = 3.90$, $p = .011$, Cohen's $d = .66$), and the same happened comparatively to the static condition, except for the palm (palm: $t(28) = 1.47$, $p = 1.00$, Cohen's $d = .25$; dorsal forearm: $t(28) = 6.32$, $p < .001$, Cohen's $d = 1.07$; ventral forearm: $t(28) = 4.61$, $p < .001$, Cohen's $d = .78$; upper arm: $t(28) = 6.72$, $p < .001$, Cohen's $d = 1.41$; back: $t(28) = 6.02$, $p < .001$, Cohen's $d = 1.02$) (see Figure 11B).

Correlations between TEAQ scores and question values showed significant positive correlations for different subscales, especially in the Attitude to Intimate Touch (See Table 12).

Table 11

Mean and Standard Deviation of the Rates for Each Question

	Other	Self
Speed		
Static	4.19 (0.95)	3.84 (1.08)
Slow	5.14 (0.13)	4.94 (0.87)
Fast	4.35 (0.15)	3.98 (1.09)
Skin Location		
Back	4.86 (0.84)	4.62 (0.98)
Upper Arm	4.43 (1.10)	4.09 (1.25)
Ventral Forearm	4.60 (0.85)	4.23 (1.10)
Dorsal Forearm	4.32 (0.77)	4.05 (0.95)
Palm	4.60 (0.86)	4.29 (1.13)
Skin Location x Speed		
Back x Static	4.38 (1.11)	4.03 (1.29)
Back x Slow	5.43 (0.93)	5.35 (0.86)
Back x Fast	4.78 (1.02)	4.49 (1.33)
Upper Arm x Static	3.82 (1.38)	3.47 (1.46)
Upper Arm x Slow	5.18 (1.21)	4.94 (1.39)
Upper Arm x Fast	4.29 (1.18)	3.86 (1.39)
Ventral Forearm x Static	4.28 (1.02)	3.85 (1.17)
Ventral Forearm x Slow	5.13 (1.02)	4.86 (1.28)
Ventral Forearm x Fast	4.38 (1.02)	3.97 (1.38)
Dorsal Forearm x Static	3.81 (1.20)	3.48 (1.35)
Dorsal Forearm x Slow	4.97 (0.84)	4.86 (0.99)
Dorsal Forearm x Fast	4.19 (0.85)	3.81 (1.14)
Palm x Static	4.67 (1.13)	4.39 (1.39)
Palm x Slow	5.01 (1.11)	4.71 (1.43)
Palm x Fast	4.13 (1.12)	3.78 (1.32)

Figure 11

(A) Pleasantness Ratings for the Question "How Pleasant do You Think that Action was for the Person Being Touched?" (B) Willingness Ratings for the Question "How Much Would You Like to be Touched Like That?"

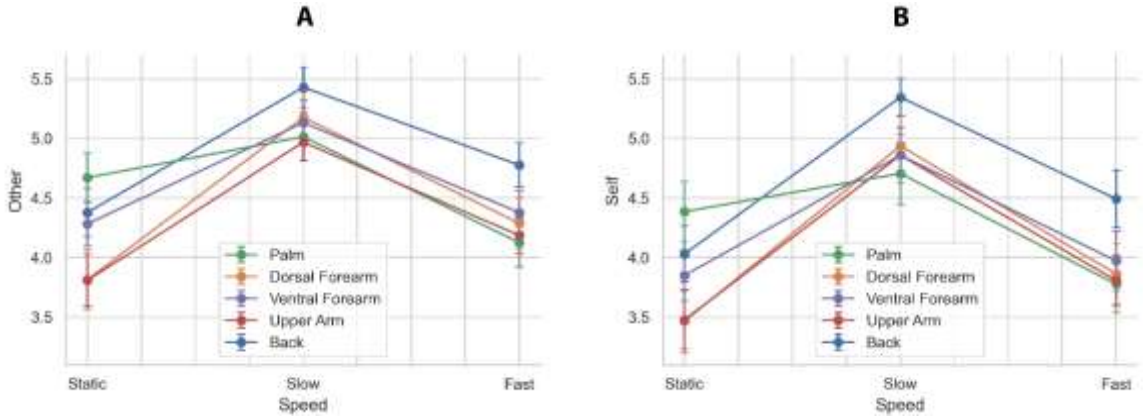


Table 12

Correlation Coefficients Between TEAQ Scores and Questions (Other and Self) Ratings

	FFT	CIT	ChT	ASC	AIT	AUT	Total
Other	.24	.34	.05	-.24	.29	.52**	.32
Self	.34	.43*	.12	-.16	.48**	.59***	.47**

Note. FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch; * $p < .05$; ** $p < .01$; *** $p < .001$.

4.4.2. Electrophysiological Data

4.4.2.1. Power Spectral Density (PSD). The mean values for the PSD results are presented in Table 13. For theta PSD (3-6 Hz), repeated measures ANOVA did not show a significant effect of speed [$F(2,56) = 1.23$, $p = .30$, $\eta_p^2 = 0.04$]. For alpha PSD (9-12 Hz), a significant main effect of speed was observed [$F(2,56) = 3.52$, $p = .036$, $\eta_p^2 = 0.11$]. Paired comparisons showed higher alpha PSD for the static condition than for the fast condition (slow vs static: $t(28) = 1.9$, $p = .13$, Cohen's $d = 0.07$; slow vs fast: $t(28) = 0.65$, $p = .51$, Cohen's $d = 0.02$; static vs fast: $t(28) = 2.56$, $p = .04$, Cohen's $d = 0.09$). Exploratory analysis of the topographical data using cluster-based permutation tests suggests that both dynamic conditions (slow and fast) are related to reduced alpha PSD than the static condition over parieto-occipital locations. Finally, ANOVA also revealed a main effect of the speed for beta PSD (16-22 Hz) [$F(2,56) = 7.40$, $p = .001$, $\eta_p^2 = 0.21$]. Post-hoc paired comparisons showed lower PSD for CT-optimal speed than the other conditions (slow vs static: $t(28) = 3.44$, $p = .003$, Cohen's $d = 0.08$; slow vs fast: $t(28) = -3.21$, $p = .004$, Cohen's $d = 0.07$; static vs fast: $t(28) = 0.22$, $p = .83$, Cohen's $d = 0.01$). Topographical exploratory data shows that slow condition is related to reduced beta PSD over a large cluster of electrodes, including posterior, central, and frontal locations (See Figure 12).

Table 13

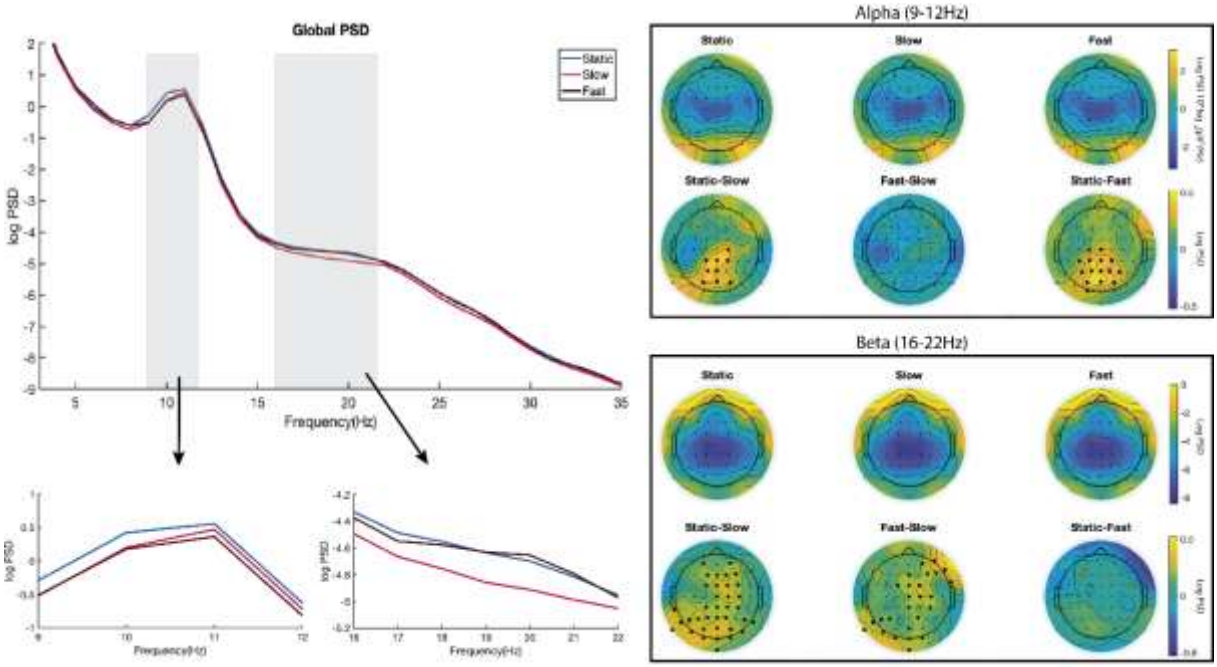
Mean and Standard Deviation of the PSD Results

	PSD		
Speed	Theta	Alpha	Beta
Static	1.40 (1.60)	0.02 (2.38)	-4.64 (2.28)
Slow	1.29 (1.65)	-0.14 (2.38)	-4.82 (2.28)
Fast	1.43 (1.86)	-0.20 (2.44)	-4.65 (2.32)

Note. PSD – Power Spectral Density.

Figure 12

(Left Panel) Mean Power Spectral Density (PSD) of All the Scalp Electrodes. (Right Panel) Topographies of Each Condition and Paired Differences of the Alpha and Beta Oscillations



Note. Alpha (9–12 Hz) and Beta (16–22 Hz) bands are shaded in grey; Bold electrodes show significant differences (using cluster-based permutation tests).

4.4.2.2. Late Positive Potential (LPP). The mean values for the LPP results are presented in Table 14. The two-way repeated measures ANOVA of the mean LPP amplitude in a window from 350 to 600 ms showed an effect of electrode [$F(2,56) = 24.57$, $p < .001$, $\eta_p^2 = 0.40$] with more positive amplitudes the more parietal the location; but no effect of speed [$F(2,56) = 1.24$, $p = .29$, $\eta_p^2 = 0.30$]. Regarding the Electrode*Speed interaction, although a higher mean LPP amplitude can be observed in the slow condition than in the other conditions over the Pz electrode, such interaction did not show significant differences. [$F(4,112) = 5.14$, $p = .06$, $\eta_p^2 = 0.01$] (See Figure 13).

Table 14

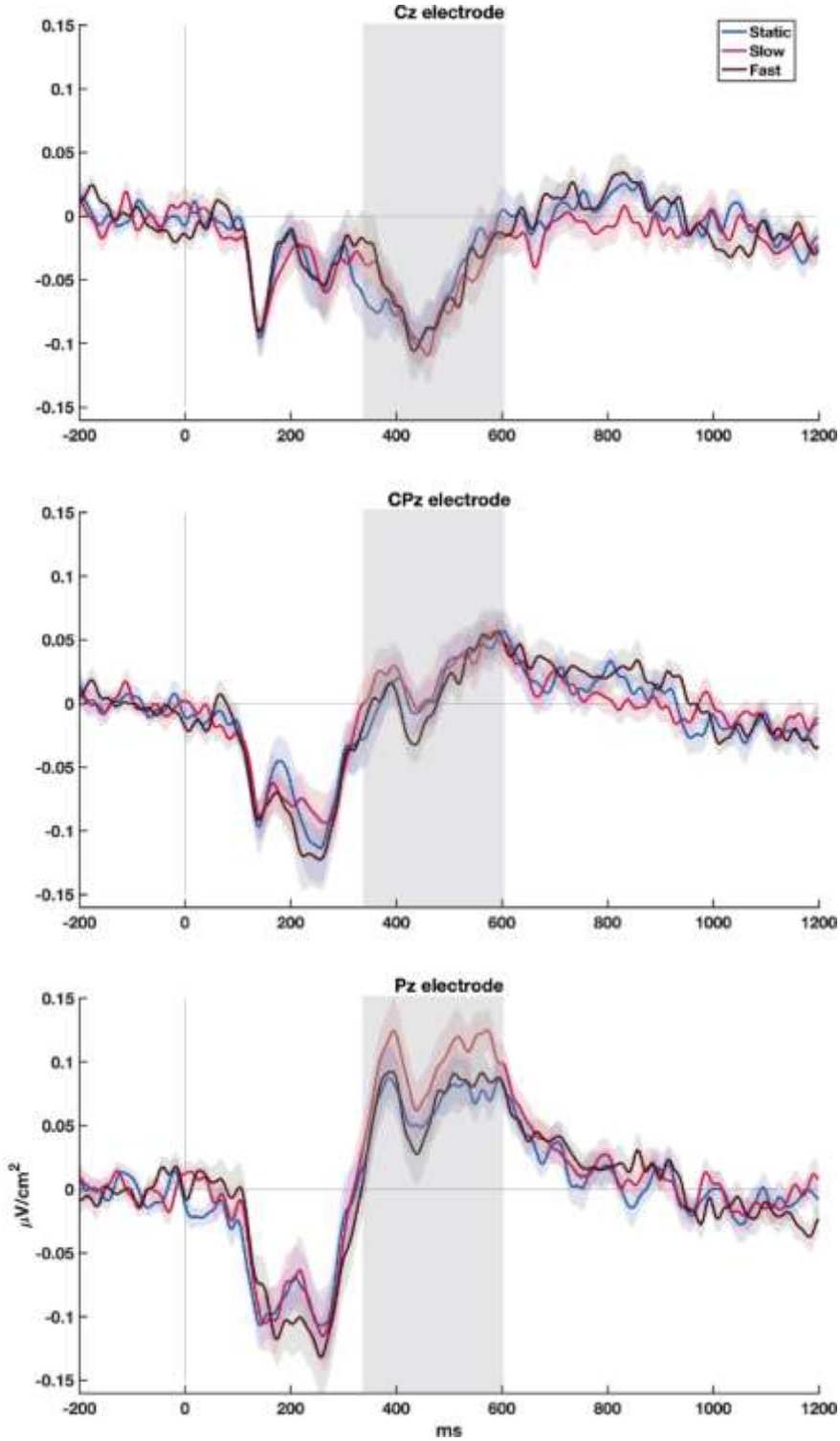
Mean and Standard Deviation of the LPP Results

	LPP		
Speed	Cz	CPz	Pz
Static	-0.06 (0.09)	0.02 (0.08)	0.07 (0.09)
Slow	-0.06 (0.08)	0.03 (0.09)	0.10 (0.10)
Fast	-0.06 (0.09)	0.01 (0.07)	0.07 (0.09)

Note. LPP – Late Positive Potential.

Figure 13

Grand Average of the Event-Related Activity Observed Over the Centro-Parietal Locations After Applying the Surface Laplacian Filter



Note. The shaded area (from 350 to 600 ms) represents the time window used to measure the mean amplitude of the LPP component for each condition; No significant differences in amplitude were observed for Speed or Speed * Electrode interaction.

4.4.2.3. Time-Frequency Analysis. The mean values for the time-frequency results are presented in Table 15. Regarding time-frequency data, the ANOVA on the mid-frontal theta oscillatory activity (3-6 Hz; 300-700 ms; Fz electrode) revealed a main effect of speed [$F(2,56) = 4.18$, $p = .031$, $\eta p^2 = 0.13$]. Post-hoc paired comparisons showed a significantly higher theta synchronisation for slow stroking speed condition than for static touch (slow vs static: $t(28) = -2.86$, $p = .018$, Cohen's $d = 0.74$; slow vs fast: $t(28) = 1.78$, $p = .16$, Cohen's $d = 0.46$; static vs fast: $t(28) = -1.08$, $p = .28$, Cohen's $d = 0.28$). Although this is the only significant difference, it is interesting to note that the slow stroking presented a higher theta synchronisation, followed by fast and by static conditions. The ANOVA on the posterior alpha activity (9-12 Hz; 300-3700 ms; PO7 and PO8 electrodes) did not show any effect of speed [$F(2,56) = 0.72$, $p = .45$, $\eta p^2 = 0.03$]. We also measured alpha activity over Rolandic locations -also called mu oscillations- (9-12 Hz; 300-3700 ms; Cz electrode) with no effect of condition [$F(2,56) = 0.84$, $p = .44$, $\eta p^2 = 0.03$]. Since the modulation of mu is also observed at more lateral locations (McFarland et al., 2000), we performed an exploratory analysis using the average of this frequency band at electrodes C1, C2, C3, and C4 in the same time-window, and again, no differences were observed between conditions [$F(2,56) = 0.95$, $p = .39$, $\eta p^2 = 0.03$]. Finally, the ANOVA on the beta band over the vertex (16-22 Hz; 300-3700 ms; Cz electrode) revealed a main effect of speed [$F(2,56) = 4.63$, $p = .014$, $\eta p^2 = 0.14$]. Post-hoc paired comparisons showed a significantly lower beta power for CT-optimal speed (slow condition) than for the two other conditions (slow vs static: $t(28) = 2.49$, $p = .031$, Cohen's $d = 0.54$; slow vs fast: $t(28) = -2.76$, $p = .023$, Cohen's $d = 0.59$; static vs fast: $t(28) = -0.26$, $p = .79$, Cohen's $d = 0.06$) (see Figure 14).

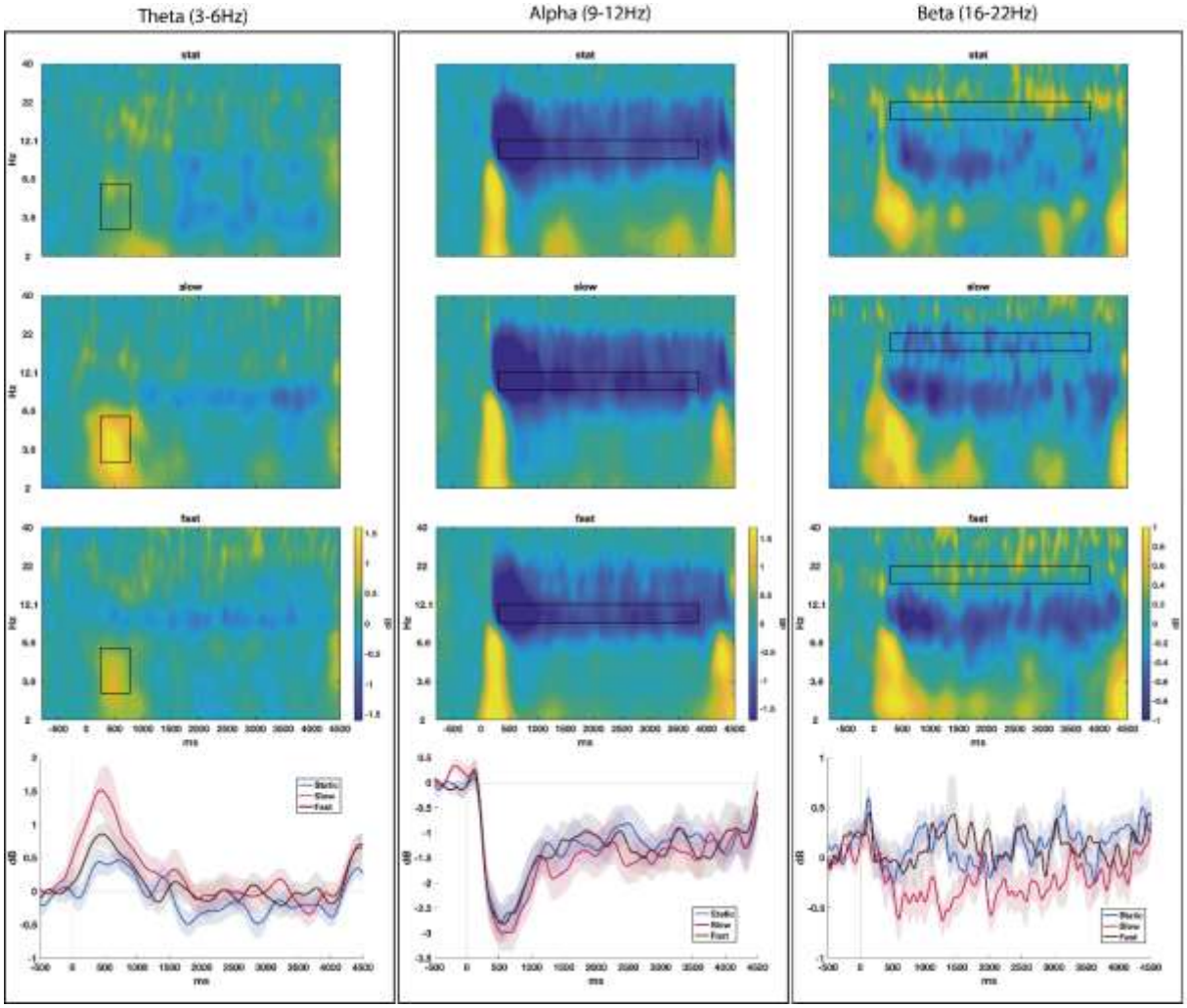
Table 15

Mean and Standard Deviation of the Time–Frequency Results

	Time-frequency				
Speed	Theta	Alpha (posterior)	Alpha (rolantic)	Alpha (C1-C4)	Beta
Static	0.41 (0.89)	-1.43 (1.84)	-0.34 (1.34)	0.03 (0.79)	0.07 (0.59)
Slow	1.38 (1.87)	-1.75 (1.93)	-0.48 (1.11)	-0.08 (1.00)	-0.30 (0.80)
Fast	0.78 (0.90)	-1.50 (1.85)	-0.61 (1.28)	-0.20 (1.05)	0.11 (0.69)

Figure 14

Event-Related Spectral Perturbation Measured Over the Most Representative Electrodes for Each Frequency (Fz for Theta, PO7 and PO8 for Alpha, and Cz for Beta)



Note. Boxes show the time and frequency ranges used to average the mean power of each analysed band (300–700 ms and 3–6 Hz for theta; 300–3700 ms and 9–12 Hz for alpha; 300–3700 ms and 16–22 Hz for beta); The bottom row shows the temporal dynamics of the time–frequency power in each condition; Statistical analyses revealed higher theta power during the slow touch condition relative to the static touch condition and a decreased beta power during slow touch in comparison to the other conditions.

4.5. Discussion

This study aimed to evaluate the valence ratings and electrophysiological correlates during the observation of short video clips of someone being touched at three different speeds: static, slow (CT-optimal speed), and fast. We found that observing interpersonal touch at CT-optimal speed was characterised by higher pleasantness and willingness ratings compared to the other CT-suboptimal speeds (static and fast touch), both in terms of perceived pleasantness for the person being touched in the video and the participants' willingness to receive a similar touch. Furthermore, beta oscillations

exhibited higher modulation for CT-optimal than CT-suboptimal touch, indicating preferred processing for vicarious interpersonal touch when delivered at speeds optimally tuned to CT receptors.

As expected, the numeric rating scale evaluations revealed higher scores for CT-optimal touch than for the other speeds, both for the perceived pleasantness that participants believed the actor in the video experienced and their own willingness to receive a similar touch. These results are consistent with previous studies using these stimuli, which also reported a very similar pattern, with higher pleasantness ratings for CT-optimal speed, particularly on the back (Haggarty et al., 2021a; Walker et al., 2017). These differences in speed ratings presumably reflect the velocity at which the CT receptors preferentially respond. Additionally, we found that the scores were correlated with individual attitudes and experiences towards touch, especially in the intimate and unfamiliar touch subscales, indicating that the perceived hedonic value of observed touch is influenced by personal touch-related experiences and emotional responses.

At the electrophysiological level, no significant differences were observed in the amplitude of the late positive potential (LPP; measured from 350 to 600 ms) during the observation of the different touch conditions. This result contrasts with the one observed by Schirmer and McGlone (2019), who found higher LPP amplitude (measured from 400 to 1000 ms) for affective touch images. A possible explanation for the discrepancy with this finding is the employment of dynamic stimuli in our study, which might cause condition effects to manifest at later latencies and in non-phase-locked activity. Another factor could be that all the touch conditions in our study involved some form of affective touch, potentially diluting any specific condition-related effects.

In time-frequency electrophysiological indices, we observed a higher mid-frontal theta power for slow than for static stimuli. Midfrontal theta is linked to cognitive control and attentional processes, primarily sourced from the anterior cingulate cortex (Cavanagh et al., 2012; Cavanagh & Frank, 2014; Clayton et al., 2015). Previous studies show that theta power typically increases after the presentation of emotionally charged stimuli (Knyazev et al., 2009; Symons et al., 2016). Our results showed that dynamic touch stimuli elicit increased activation of frontal attentional areas, particularly for the CT-optimal condition, although differences between slow and fast touch were not significant. These findings partially contrast with von Mohr et al. (2018), who found higher tonic theta suppression for slow stroking when compared to static stroking and attributed this correlate to the involvement of attentional-emotional regulatory processes. Here we do not find a reduction of theta in PSD values, possibly due to differing methodologies. Put in common with our time-frequency findings, the touch observation at CT-optimal

velocities may engage greater initial attentional resources (compared to static touch), however, these differences in attentional engagement do not appear to be maintained throughout the video.

In alpha/mu activity, we found higher alpha PSD for static compared to fast touch, however exploratory topographic analysis revealed that both dynamic conditions exhibited reduced power than the static condition over parieto-occipital regions than the static condition. Posterior alpha synchronisation typically indicates cortical inhibition, while its desynchronisation is often associated with enhanced visual attention and motion processing (Griffiths et al., 2019; Jensen & Mazaheri, 2010; Klimesch, 2012; Pfurtscheller & Lopes da Silva, 1999; Salamanca-Giron et al., 2021). In our study, the reduction in alpha power during dynamic conditions may reflect increased attentional engagement and visual motion processing, due to moving touch. Mu oscillations are another EEG rhythm in the alpha range but are recorded from central areas, which often makes them difficult to distinguish from alpha activity (Charidza and Gillmeister, 2022). In this respect, the fact that the differences between static and dynamic conditions have a parieto-occipital topography suggests that part of these differences may be affected by differences in central mu activity, and not only in posterior alpha. Time-frequency analysis did not reveal significant differences in posterior alpha power across conditions - analysed over the electrodes that showed the highest power modulation. Although we expected that videos at optimal speeds for CT receptors would cause increased alpha desynchronisation, since it has been related in the literature to a greater attentional capture (Sauseng et al., 2005), our results suggest that this index at more posterior locations is not sensitive to the dynamic and valence characteristics of the stimuli. Similar negative results were observed for time-frequency data in this band over the vertex. This underscores the value of using both PSD and time-frequency analyses to capture different aspects of neural responses, as they provide complementary indices. While PSD (the way it was calculated here) provides a global index of power modulations, time-frequency analysis is more targeted, performed over specific scalp locations, frequencies, and temporal windows.

Beta band power reduction, followed by an increase after movement cessation, is a neural correlate of somatosensory cortex activation observed during both actual and imagined movement (Pfurtscheller et al., 2005), as well as during action observation (Babiloni et al., 2002), and it seems to be related to the activation of the so-called "mirror-like system" and empathic processes (Riečanský et al., 2020). In this study, beta showed lower power specifically for slow touch compared to CT-suboptimal conditions. These findings contrast with prior research involving direct skin stimulation, which indicated greater activation of the Rolandic areas during fast touch (Case et al., 2016; Schirmer et al. 2022), likely due to increased activity of other mechanoreceptors, which ultimately project to the somatosensory cortex (Löken

et al., 2009). However, our results during observation align with the literature indicating that beta suppression reflects more neural resources engagement and elicits higher activation of both emotional and somatosensory processing networks (Charidza & Gillmeister, 2022). As prior research shows, beta suppression in response to affective stimuli like touch is linked to the brain's integration of sensory inputs with emotional significance and motor preparation. This suggests that the CT condition, which is biologically and socially relevant touch, seems to recruit more attentional and emotional resources, as demonstrated by heightened beta suppression (Babiloni et al., 2016; Perry et al., 2010). In our exploratory study using dots as stimuli, we did not find evidence that beta suppression was significantly higher for the slow movement, suggesting that the effects observed for social touch videos are not solely driven by low-level visual differences related to speed but rather by the affective and somatosensory relevance of the stimuli. However, the findings of the exploratory study should be considered tentative pending confirmation in a larger sample.

Additionally, reduced beta power points to the importance of visual motion processing in vicarious touch (Charidza & Gillmeister, 2022), indicating that this neural response is not isolated to touch-specific regions but involves a broad, integrated network for processing socially relevant stimuli. Our results were also consistent with findings that higher beta desynchronisation over sensorimotor areas occurs during the observation of moving stimuli, such as a moving hand, compared to the observation of a static hand or bouncing balls (Puzzo et al., 2011). This is also consonant with the higher beta desynchronisation reported for the observation of needle insertion in persons of the same ethnicity, compared to persons of different ethnicity, suggesting that the more relevant ingroup-related information evokes increased resonant activity of sensorimotor cortex (Riečanský et al., 2015). Our data points out that such event-related desynchronisation (ERD) is not exclusive of negatively valenced stimuli but is also observed during pleasant touch.

Our results showed discrepancies with the study of Schirmer and McGlone (2019) who found higher beta power during the observation of static images with social touch vs no touch, probably due to the dynamic nature of our videos. The use of dynamic videos, unlike static images, likely influenced beta power by engaging additional neural processes related to movement and time-dependent sensory changes, which require more sensorimotor integration and attentional resources. Given that beta ERD is related to increased corticospinal excitability (Chen et al., 1998; Kraus et al., 2016), our results suggest that observing touch at CT-optimal speed may lower the threshold for producing motor responses.

Literature results on electrophysiological indices related to the characterisation of interpersonal touch at CT-optimal (and CT-suboptimal) speed responses (either actual or observed touch) have shown

some variance and inconsistency. Given these inconsistencies, in future research it would be important to use study paradigms that directly compare actual and vicarious touch. Furthermore, a potential shortcoming of the present study is that the videos depict a woman touching a man, both Caucasian young adults. Future studies should consider factors like sex, gender, age, and ethnicity (both giver and receiver), as these variables can influence empathic processes. In addition, the observed differences in pleasantness across body locations may also be reflected in electrophysiological indices, though our study did not distinguish between body parts due to the need for more epochs to ensure a good signal-to-noise ratio. Future research should explore electrophysiological responses to affective touch in various body locations. Overall, the observed beta suppression, which is thought to reflect sensorimotor engagement and affective processing, appears to be more closely linked to the biological and social relevance of CT-optimal touch rather than being driven purely by visual motion differences. However, future studies should directly manipulate visual speed-controlled conditions to further disentangle these effects. Additionally, separating analyses for hairy and non-hairy skin areas and accounting for these factors with sufficient trials could help clarify the impact of body region and speed on the results. Understanding the CT system's role in conditions such as autism spectrum disorder (Croy et al., 2016; Kaiser et al., 2016; O. Miguel et al., 2017; Voos et al., 2013), psychopathy (Waller et al., 2021), depression (Takeuchi et al., 2010), anorexia nervosa (Crucianelli et al., 2016), and chronic pain (Krahé et al., 2016; Liljencrantz et al., 2016, 2017) could provide valuable insights into its influence on neurodevelopment and sensory processing in clinical populations. Visual stimuli of affective touch, like those used here, may be a useful proxy to better understand the potential alterations of this somatosensory modality in different clinical populations.

4.5.1. Conclusions

In conclusion, our results suggest that vicarious processing of affective touch, particularly at CT-optimal speeds, engages more attentional resources and modulates somatosensory-related activity more significantly than static touch, as evidenced by increased mid-frontal theta power and reduced beta power respectively. Although both dynamic touch stimuli (slow and fast) showed a higher alpha/mu power reduction compared to static touch (presumably due to the visual changes that the dynamic stimuli have), this measure did not distinguish between CT-optimal and fast speeds. Overall, our findings provide evidence for the preferential processing of ecologically relevant touch-related information when delivered at speeds that are optimal for C-Tactile receptors.

4.6. References

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CHAPTER 5

Vicarious Perception of Touch in ASD: The Role of Empathy and Touch Experiences

Chapter 5. Vicarious Perception of Touch in ASD: The Role of Empathy and Touch Experiences

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Supplementary material can be found in Appendix C.

5.1. Abstract

C-Tactile (CT) targeted affective touch plays a central role in social cognition and emotional development. In autism, atypical sensory processing, particularly in response to tactile stimulation, has frequently been reported. Autistic individuals have been shown to exhibit altered perception and reduced hedonic evaluation of affective touch, as well as increased defensive responses. Despite these differences in direct touch, the perception of vicarious social touch or its connection to social and emotional constructs remain poorly explored. Vicarious touch is theoretically relevant because it recruits social-cognitive and affective mechanisms beyond primary somatosensory processing; however, most prior studies have focused on neural correlates in neurotypical adults, with limited behavioural investigation and scarce evidence in autistic populations. The present study evaluated how autistic and non-autistic adolescents and young adults perceive vicarious social touch. Participants observed videos depicting touch delivered at three different speeds (static, CT-optimal, and fast) and across five skin locations (back, upper arm, ventral forearm, dorsal forearm, and palm). Participants provided subjective ratings of how pleasant they believed the touch was for the person in the video (numeric rating scale (NRS) Other/pleasantness) and how much they would like to be touched in the same way (NRS Self/willingness). We also examined associations with empathy and touch-related attitudes. Results showed no group differences in the pleasantness and willingness ratings. However, a significant three-way interaction between speed, skin location, and group emerged for the NRS Self. Across both groups, ratings indicated that speed and skin location modulated ratings, with CT-optimal stroking and touch in the back rated as most pleasant. For NRS Self, male participants reported higher pleasantness than females, across groups. Pleasantness and willingness ratings were positively correlated with attitudes toward touch from friends and family and toward self-care, but not with other touch-related attitudes or empathy scores, across groups. Finally, autistic individuals reported significantly lower empathy and less positive touch-related experiences than non-autistic participants. Overall, these findings suggest that global vicarious touch perception may be relatively preserved in autistic adolescents and young adults, while individual differences in empathy and touch-related experiences may contribute to broader variability in social touch processing.

5.2. Introduction

Touch experiences play a fundamental role in human development and social interactions, underpinning our interpersonal communication, emotional bonding, and well-being (Cascio et al., 2019; Morrison et al., 2010; Olausson et al., 2010; Walker & McGlone, 2013). From infancy, touch is essential for cognitive, brain, and socioemotional development (Field, 2001; Hertenstein, 2002; Stack, 2001), and it contributes to attachment by conveying affection, comfort, and security, thereby supporting the establishment of essential social bonds (Hertenstein, 2002). A growing body of research suggests that interpersonal communication via touch may be modulated by affective touch, which is hypothesised to be primarily conveyed through C-Tactile (CT) afferents. These are a specialised subclass of low-threshold mechanoreceptive C-fibres (Nordin, 1990; Vallbo et al., 1993, 1999), that respond optimally to gentle and caress-like stroking (Olausson et al., 2010; Vallbo et al., 1993), at slow speeds (i.e., between 1-10 cm/s) (Ackerley et al., 2014; Löken et al., 2009; Olausson et al., 2016). This speed, referred to as "CT-optimal", is commonly perceived as pleasant and associated with social bonding (Ackerley et al., 2014; Essick et al., 1999, 2010; Löken et al., 2009; McGlone et al., 2014). However, touch perception and interpretation can vary across individuals and are shaped not only by sensory input but also by higher-level influences such as personal experiences, social context, and neurodevelopmental differences, including those seen in autism spectrum disorder (ASD).

ASD is characterised by impairments in social communication and interaction, as well as restrictive, repetitive, and stereotypical behaviours and interests (American Psychiatric Association, 2022). Additionally, autistic individuals often present atypical patterns of sensory-perceptual processing including hyper- or hyposensitivity to tactile, auditory, and visual stimuli (Baker et al., 2008; Baranek et al., 2006; Brandwein et al., 2015; Marco et al., 2011). Among the sensorial modalities, altered responses to tactile stimulation have been most frequently reported in autistic individuals, including atypical responses to textures, difficulties in adapting behaviour based on previous sensory experiences, and an intense interest in the sensory features of objects (Tomchek & Dunn, 2007). These sensory processing differences in ASD can affect how individuals respond to sensory stimuli, including touch, which can be uncomfortable or overwhelming (American Psychiatric Association, 2022; Tomchek et al., 2018). These individuals may exhibit either heightened or reduced sensitivity to tactile stimuli, which can influence how they experience touch during social interactions and, consequently, impact their ability to form and maintain social bonds (Foss-Feig et al., 2012; Reynolds et al., 2011; Tomchek et al., 2018). These sensory processing differences have also been linked to the prediction of social problems (O. Miguel et al., 2017).

Research has increasingly focused on the affective dimensions of tactile processing in ASD, indicating that autistic individuals may process affective tactile stimuli differently, particularly those mediated by the CT afferents. Converging evidences point to atypical functioning of the CT system in this population (Bufo et al., 2022; Capiotto et al., 2024; Cascio et al., 2016; Jackson et al., 2022; Li et al., 2022). Several studies have shown that autistic individuals often exhibit reduced discrimination or lower pleasantness ratings in response to CT-optimal stroking, along with more defensive or avoidance reactions to tactile stimuli from others than non-autistic individuals (Baranek et al., 2006; Cascio et al., 2016; Foss-Feig et al., 2012; Kaiser et al., 2016), potentially perceived as less socially meaningful and not reinforcing (Jackson et al., 2022). Furthermore, affective touch in autistic children tends to elicit more defensive responses, particularly in areas of the body with a high density of CT afferents (e.g., forearm), compared to areas with lower CT innervation (e.g., palm) (Cascio et al., 2016). Using the same video stimuli employed in the present study, Haggarty et al. (2021a) showed that among non-autistic adults, higher autistic traits were associated with negative pleasantness ratings, particularly for touch delivered to the palm. In the same study, the authors also reported that autistic and non-autistic children did not differ in their pleasantness ratings of observed touch, despite parental reports indicating that autistic children exhibited significant somatosensory sensitivities. These findings highlight that even subclinical autistic traits, particularly those related to social and communication challenges, may modulate the perception of affective touch.

Alterations in the response to affective touch in ASD may also reflect broader differences in social cognition abilities, such as empathy. Empathy is frequently reported to be altered in autistic individuals (Fatima & Babu, 2024; Harmsen, 2019). It is often divided into cognitive and affective components, the ability to understand another person's mental state and the capacity to share and respond to others' emotional experiences, respectively (Decety & Jackson, 2004). Cognitive empathy is consistently reported to be impaired in autistic individuals (Blair, 2005; Bons et al., 2013; Deschamps et al., 2014; Dziobek et al., 2008; Hadjikhani et al., 2014; Mathersul et al., 2013; Mazza et al., 2014; Rueda et al., 2015; Schwenck et al., 2012; Shamay-Tsoory et al., 2002). However, affective empathy findings have been more variable across studies, some suggest that affective empathy remains relatively intact, with no differences when compared with non-autistic individuals (Bons et al., 2013; Deschamps et al., 2014; Dziobek et al., 2008; Hadjikhani et al., 2014; Rueda et al., 2015; Schwenck et al., 2012), while others report a reduction in this capacity among autistic individuals (Blair, 2005; Mathersul et al., 2013; McIntosh et al., 2006; Minio-Paluello et al., 2009; Shamay-Tsoory et al., 2002). Such variability highlights

the importance of considering empathy differences in interpreting how autistic individuals perceive and interpret social cues conveyed through touch (Cascio et al., 2012).

Despite the growing body of literature reporting atypical responses to affective touch in autism, much less is known about how autistic individuals perceive vicarious social touch. Vicarious touch perception is important because it engages not only affective tactile processing but also higher-order social-cognitive and emotional mechanisms (e.g., empathy) beyond primary somatosensory input. Previous literature has mainly focused on neural correlates in neurotypical adults, with comparatively limited behavioural evidence and scarce data from autistic populations. Therefore, it remains unclear how vicarious touch perception relates to broader socio-emotional traits and whether alterations reported for direct affective touch generalise to observed social touch. Recent literature has also highlighted the distinction between self- and other-referred vicarious touch, showing that both are selectively attuned to CT-optimal stimulation but may rely on partially distinct neurocognitive mechanisms (Butti et al. 2024). This distinction supports the conceptual separation between pleasantness attributed to others' touch and one's own willingness to receive similar touch.

This study provides a novel contribution by extending previous behavioural and neuroimaging research on direct affective touch to the domain of vicarious social touch, investigating how autistic adolescents and young adults (vs non-autistic individuals) perceive vicarious social touch using ecologically valid stimuli. It also explores how empathy and touch-related experiences and attitudes modulate this perception, an approach that integrates both sensory and socio-emotional dimensions of touch processing, which remain underexplored in this population. Using validated video stimuli (Crucianelli et al., 2022; Devine et al., 2020; Haggarty et al., 2021a, 2021b; Pereira et al., 2025; Walker et al., 2017), participants rated the pleasantness of observed touch by the person in the video and their willingness to receive similar touch across different body locations (e.g., back, forearm, palm) and speeds (static, CT-optimal, and fast). They also completed the Touch Experiences and Attitudes Questionnaire (TEAQ) and the Basic Empathy Scale (BES) questionnaires. We hypothesised that autistic participants would report lower pleasantness/willingness ratings, particularly for CT-optimal touch and touch at skin locations with higher CT afferent density. We also expected lower scores on positive interpersonal and self-care touch experiences (all TEAQ subscales), and on both cognitive and affective empathy in the autistic group. Furthermore, we predicted that more positive touch experiences (TEAQ subscales: friends and family touch (FFT) and childhood touch (ChT)) and greater self-care attitudes (TEAQ subscale: attitude to self-care (ASC)) would be associated with higher pleasantness ratings of observed touch, while discomfort with unfamiliar touch (TEAQ subscale: attitude to unfamiliar touch (AUT)) would predict lower

ratings. Finally, we expected higher empathy scores to be linked to greater willingness to receive similar touch.

5.3. Methods

5.3.1. Participants

The study included 86 adolescents and young adults, among them 46 participants with a formal autism diagnosis from specialised clinicians (15 females, aged 11 to 25 years, M =16.04; SD = 2.99) and 40 participants without an autism diagnosis (21 females, aged 11 to 18 years, M = 15.98; SD = 2.34). A priori power analysis using G*Power indicated that a sample size of 46 was sufficient to detect a medium effect (f = 0.25) with 91% power (α = .05). All participants reported normal or corrected-to-normal vision. Additional characteristics of the sample are included in Table 1. Exclusion criteria included the absence of speech acquisition and severe communication difficulties that would prevent completion of the experimental tasks for autistic individuals, and the presence of head injury or other current neurological or psychiatric conditions for the non-autistic group. Participants were recruited through associations, and they received no compensation for their participation. Informed consent was obtained from participants or their legal guardians when applicable. The study was approved by the ethics committee for Research in Health and Life Sciences at the University of Minho (CEICSH 023/2020) and by the Galician Ethic Committee for Clinical Research with ethics board protocol number 2020/400. This study is performed in line with the principles of the Declaration of Helsinki.

5.3.2. Procedure and Psychosocial Assessment

Participants first completed a socio-demographic questionnaire, the TEAQ (Pereira et al., 2023a; the Spanish version is currently in preparation and was presented in preliminary form at a conference (Pereira et al., 2023b)), and the BES (Jolliffe & Farrington, 2006). During the assessment session with autistic participants, their parents completed the CBCL (Achenbach & Rescorla, 2001), to assess behavioural outcomes. This study is part of a broader project, through which the Intelligence Coefficient (IC) of the participants with autism had already been obtained. IC and CBCL scores were collected solely for sample characterization in the ASD group and were not included in the main analyses. Following this phase, participants completed the experimental task, which will be discussed in greater detail in Section 5.3.3. Participants completed the study's phases individually on a computer, with a researcher present to provide instructions and support as needed.

The TEAQ is a self-report instrument that assesses experiences and attitudes toward touch across childhood and adulthood. In this study, only 4 of the 6 subscales were included: Friends and Family Touch (FFT), evaluating interpersonal touch with friends and family, Childhood Touch (ChT), assessing positive touch experiences in childhood, Attitude to Self-Care (ASC), focusing on grooming and self-care behaviours, and Attitude to Unfamiliar Touch (AUT), concerning attitudes toward touch from strangers. Subscales related to intimate touch – current experiences and attitudes to intimate touch – were excluded, as the sample consisted of minors. Each item is rated on a 5-point Likert scale from 1 ('Disagree strongly') to 5 ('Agree strongly'). Higher scores indicate more positive attitudes or more frequent touch experiences.

The BES is a self-reported questionnaire that evaluates both cognitive and affective components of empathy, providing insight into participants' ability to understand and share others' emotional states. The questionnaire is rated on a 5-point Likert scale from 1 ('Strongly disagree') to 5 ('Strongly agree'). Higher scores indicate greater empathic ability.

The CBCL is a parent/caregiver report that assesses the frequency of behavioural problems on a 3-point Likert scale: 0 (''Behavioural absent''), 1 (''Behaviour present sometimes''), and 2 (''Behavioural presents frequently''). It measures children and adolescents' emotional, behavioural, and social problems and consists of eight syndrome scales: anxious/depressed, withdrawn/depressed, somatic complaints, social problems, thought problems, rule-breaking behaviour, and aggressive behaviour. In this study, we only used the Social Problems subscale which is summed and then converted into standardised T-scores based on age and sex.

The Intelligence Coefficient was assessed using different standardized instruments appropriate to the participant's age, including the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003), the Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III; Wechsler, 2002), the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997), and the Reynolds Intellectual Assessment Scales (RIAS; Reynolds & Kamphaus, 2003).

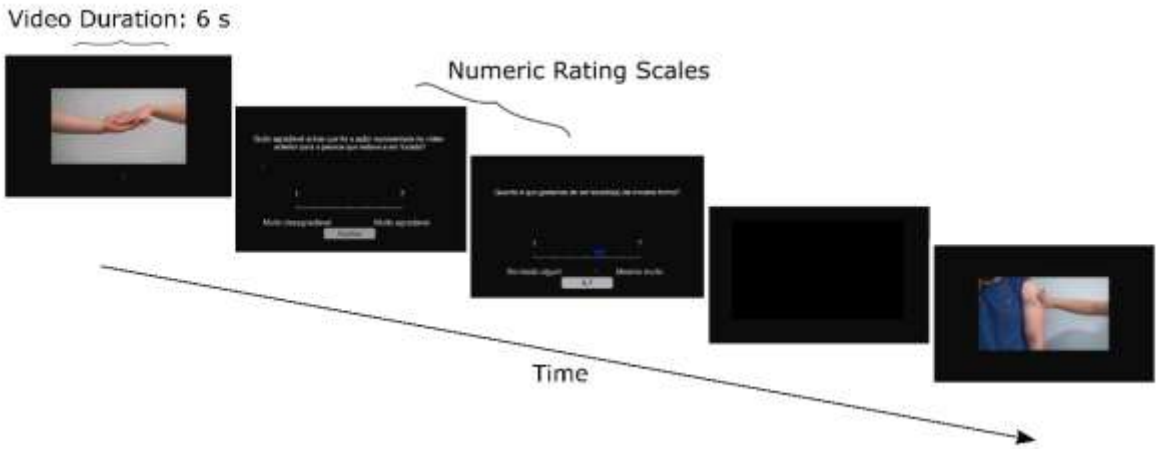
5.3.3. Experimental Task

The experimental task involved participants viewing a set of 15 short videos (6 seconds each), depicting an actor being touched by another at five distinct skin sites (back, upper arm, ventral forearm, dorsal forearm, and palm). The touches were performed at three speeds: static (0 cm/s), CT-optimal speed (3 cm/s), and fast/non-CT-optimal (30 cm/s). These speed terms will be used to refer to the different velocities throughout the paper. The videos were used in previous research by Walker et al. (2017), Devine et al. (2020), Haggarty et al. (2021a, 2021b), Crucianelli et al. (2022), and Pereira et al.

(2025). Each of the 15 videos was presented once to each participant in a randomised order, with stimulus order randomised across participants and no formal counterbalancing applied. Participants were informed that they would be viewing videos of social interactions and would need to answer the two specified questions. After every video, participants responded to two questions using a numeric rating scale (NRS): "How pleasant do you think that action was for the person being touched?" (referred to as "NRS Other"/pleasantness), and "How much would you like to be touched like that?" (referred to as "NRS Self"/willingness). Ratings were made on a 1–7 numeric scale using a slider interface, with endpoints labelled ("Not at all" to "Extremely"). These questions were always asked consecutively and in the same order. This task was carried out using the Pavlovia online platform. See Figure 15 for a visual outline.

Figure 15

Task Timeline



Note. Each 6-second video depicted a forearm touching another person at five different skin locations and three different speeds; Each trial began with a 1-second blank screen, followed by the video. After the video, participants answered two questions in a fixed order: (1) how pleasant they believed the touch was for the person being touched, and (2) how pleasant they would find receiving that touch themselves; using a computer mouse on a scale from 1 to 7; There was no time limit for these responses; Once both questions were completed, a 1-second blank screen was presented before the next trial.

5.3.4. Statistical Analysis

Statistical analyses were performed using JASP software (version 0.18.3). To analyse differences between groups (autistic vs non-autistic), we performed an independent-samples *t*-test and two repeated-measures ANOVAs. For the independent-samples *t*-test, we compared the TEAQ subscales scores, the BES subscales scores, and the NRS ratings (both Self and Others, the average of all the ratings aggregating the 3 speeds and the 5 skin locations). For the independent samples *t*-test Cohen's *d* was calculated to estimate effect sizes. We conducted two repeated measures ANOVAs (for both NRS Self and

Others), using the skin locations (back, upper arm, ventral forearm, dorsal forearm, and palm) and the speed of stroking (static, slow, and fast) as within-subject factors, and the sex and group as between-subject factors. The Greenhouse-Geisser correction was applied when the assumption of sphericity was violated and post-hoc paired comparisons were computed with the Holm correction. Partial Eta Squared (η_p^2) and Cohen's *d* were calculated to estimate effect sizes. Furthermore, we conducted Pearson's correlations to explore the relation between NRS ratings (both Self and Others) and TEAQ and BES subscales, Fisher's *z* was calculated to estimate effect sizes, and *p*-values were adjusted using the False Discovery Rate (FDR) correction to account for multiple comparisons. A multiple linear regression analysis was conducted to examine the extent to which touch experiences (TEAQ subscales), empathy (BES subscales), and group (autistic vs non-autistic) predicted perceived touch pleasantness/willingness (NRS Self and NRS Other ratings). Bayesian statistics were applied to complement the frequentist statistical results and quantify the strength of evidence for or against the null hypothesis. For each analysis (independent samples *t*-test, repeated measures ANOVAs, Pearson's correlations, and multiple linear regressions), Bayes factors (BF_{10}) were computed in relation to the null hypothesis. This approach allowed us to better interpret non-significant results and assess the robustness of the findings beyond *p*-values. Cases with missing data were excluded from the corresponding statistical analyses, which were conducted using only available data.

Jamovi (version 2.7.18) was used to carry out regression analyses on the two questions separately, to determine whether a quadratic expression described significantly more of the variance than a linear expression alone. Multi-level modelling (Linear Mixed Models) was used, including participant as a random factor, while velocity (linear and quadratic) and group (Controls vs ASD) were included as fixed factors. The outcome variable was NRS Self and Other (willingness/pleasantness) ratings. Analyses were carried out for each location individually, as well as in a full model comparing the effect of velocity across all hairy skin locations to the hand, including interaction terms between velocity, location, and group. Model residuals were examined using Q-Q plots and histograms to verify the assumption of normality; no outliers were identified.

5.4. Results

The sociodemographic characteristics, TEAQ and BES scores, and NRS ratings of the two groups are presented in Table 16.

Table 16

Sociodemographic Characteristics, TEAQ and BES Scores, and NRS Ratings of the Sample (n Total = 86, ASD n = 46, and Controls n = 40)

Variable	ASD		Controls		t/X^2	p
	Mean	Range	Mean	Range		
Age, y	16.05 ± 2.99	11-25	15.98 ± 2.34	11-18	0.12	.907
Sex, % female	32.61	-	52.50	-	3.48	.062
Nationality, % Spanish					22.61	< .001
Spanish	100	-	60.00	-	-	-
Portuguese	-	-	40.00	-	-	-
Current school attendance, %	93.48	-	97.50	-	0.78	.377
Current work, %	6.52	-	2.50	-	0.78	.377
Intelligence Coefficient (*n* = 35 ASD)	106.63 ± 19.14	72-139	-	-	-	-
CBCL (*n* = 42 ASD)						
Social problems	72.64 ± 14.49	48-100	-	-	-	-
TEAQ (*n* = 86)						
FFT	2.86 ± 0.83	1.00-4.27	3.76 ± 0.79	1.91-5.00	-5.12	< .001
ChT	3.99 ± 0.76	1.33-5.00	4.15 ± 0.74	1.50-5.00	-1.01	.315
ASC	2.37 ± 0.75	1.00-4.20	3.27 ± 1.51	1.00-5.00	-4.22	< .001
AUT	2.64 ± 0.78	1.20-4.60	3.19 ± 0.79	1.80-4.80	-3.21	.002
BES (*n* = 86)						
Cognitive	3.50 ± 0.40	2.33-4.22	4.16 ± 0.44	3.44-5.00	-7.29	< .001
Affective	3.19 ± 0.43	2.22-4.00	3.66 ± 0.59	2.67-5.00	-4.28	< .001
NRS						
Self (*n* = 86)	4.13 ± 0.90	1.68-6.30	4.14 ± 0.72	2.34-5.76	-0.06	.949
Other (*n* = 86)	3.51 ± 1.12	1.05-5.60	3.93 ± 0.90	1.40-5.71	-1.89	.063

Note. y – years; CBCL – Child Behaviour Checklist; TEAQ – Touch Experiences and Attitudes Questionnaire; FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch; BES – Basic Empathy Scale.

5.4.1. Associations with Questionnaire Measures

5.4.1.1. Correlations Between NRS Ratings and Touch and Empathy Questionnaires Scores.

For the autistic individuals, NRS Self ratings showed a positive correlation with the ASC TEAQ subscale ($r(44) = 0.52$, $p_{fdr} < .001$, Fisher's $z = 0.58$, $BF_{10} = 159.26$), indicating decisive evidence of an

association. No significant correlations were found with the remaining TEAQ subscales (FFT: $r(44) = 0.21$, $p_{fdr} = .293$, Fisher's $z = 0.21$, $BF_{10} = 0.46$; ChT: $r(44) = -0.22$, $p_{fdr} = .293$, Fisher's $z = -0.22$, $BF_{10} = 0.51$; AUT: $r(44) = -0.15$, $p_{fdr} = .404$, Fisher's $z = -0.15$, $BF_{10} = 0.29$), and with the two BES subscales (cognitive: $r(44) = 0.22$, $p_{fdr} = .293$, Fisher's $z = 0.22$, $BF_{10} = 0.52$; affective: $r(44) = 0.09$, $p_{fdr} = 596$, Fisher's $z = 0.09$, $BF_{10} = 0.22$), indicating anecdotal (FFT, ChT and BES cognitive) and substantial (AUT and BES affective) evidence for the absence of an association. For the NRS Other ratings, autistic participants showed a positive correlation with the FFT TEAQ subscale ($r(44) = 0.53$, $p_{fdr} < .001$, Fisher's $z = 0.58$, $BF_{10} = 171.23$), and with the ASC TEAQ subscale ($r(44) = 0.57$, $p_{fdr} < .001$, Fisher's $z = 0.65$, $BF_{10} = 605.25$), both indicating decisive evidence of an association. No significant correlations were found with the remaining TEAQ subscales (ChT: $r(44) = 0.02$, $p_{fdr} = .878$, Fisher's $z = 0.02$, $BF_{10} = 0.19$; AUT: $r(44) = 0.15$, $p_{fdr} = .404$, Fisher's $z = 0.15$, $BF_{10} = 0.30$) and with the two BES subscales (cognitive: $r(44) = 0.18$, $p_{fdr} = .333$, Fisher's $z = 0.19$, $BF_{10} = 0.38$; affective: $r(44) = 0.21$, $p_{fdr} = .293$, Fisher's $z = 0.22$, $BF_{10} = 0.49$), indicating substantial (ChT and AUT) and anecdotal (BES subscales) evidence for the absence of an association.

For non-autistic individuals, no significant correlations were found between NRS ratings and the questionnaires (NRS Self: FFT: $r(44) = 0.11$, $p_{fdr} = .645$, Fisher's $z = 11$, $BF_{10} = 0.25$; ChT: $r(44) = 0.31$, $p_{fdr} = .204$, Fisher's $z = 0.32$, $BF_{10} = 1.24$; ASC: $r(44) = 0.14$, $p_{fdr} = .645$, Fisher's $z = 0.14$, $BF_{10} = 0.28$; AUT: $r(44) = 0.14$, $p_{fdr} = .645$, Fisher's $z = 0.14$, $BF_{10} = 0.28$; cognitive empathy: $r(44) = 0.18$, $p_{fdr} = .645$, Fisher's $z = 0.18$, $BF_{10} = 0.36$; affective empathy: $r(44) = 0.33$, $p_{fdr} = .204$, Fisher's $z = 0.35$, $BF_{10} = 1.62$; and NRS Other: FFT: $r(44) = 0.06$, $p_{fdr} = .785$, Fisher's $z = 0.06$, $BF_{10} = 0.21$; ChT: $r(44) = 0.32$, $p_{fdr} = .204$, Fisher's $z = 0.33$, $BF_{10} = 1.42$; ASC: $r(44) = 0.10$, $p_{fdr} = .660$, Fisher's $z = 0.10$, $BF_{10} = 0.23$; AUT: $r(44) = 0.14$, $p_{fdr} = .645$, Fisher's $z = 0.14$, $BF_{10} = 0.28$; cognitive empathy: $r(44) = 0.02$, $p_{fdr} = .927$, Fisher's $z = 0.02$, $BF_{10} = 0.20$; affective empathy: $r(44) = 0.12$, $p_{fdr} = .645$, Fisher's $z = 0.02$, $BF_{10} = 0.25$). These results indicate substantial evidence for FFT, ASC, and AUT (in both NRS Self and Other) and for cognitive and affective empathy (in NRS Other) for the absence of an association. Additionally, results indicate anecdotal evidence for the absence of an association for cognitive empathy (in NRS Self), and anecdotal evidence of an association for ChT (in both NRS Self and Other) and affective empathy (in NRS Self).

5.4.1.2. Linear Regressions Between NRS Ratings and Touch and Empathy Questionnaires Scores. For the NRS Self ratings, no significant regression model was found with the TEAQ and BES subscales as predictor factors [$F(7,78) = 1.38$, $p = .224$].

For the NRS Other ratings, the overall regression model was significant [$F(7,78) = 2.85$, $p = .011$], explaining approximately 20.4% of the variance in the NRS Other scores ($R^2 = 0.204$, adjusted $R^2 = 0.132$). Despite this, no significant predictors were found for the TEAQ subscales (FFT: $\beta = 0.25$, $t = 1.69$, $p = .095$, $BF_{10} = 107.83$; ChT: $\beta = 0.06$, $t = -0.49$, $p = .622$, $BF_{10} = 0.60$; ASC: $\beta = 0.25$, $t = 1.83$, $p = .071$, $BF_{10} = 20.22$; AUT: $\beta = 0.17$, $t = 1.55$, $p = .125$, $BF_{10} = 1.07$), nor for the empathy measures of BES subscales (cognitive: $\beta = -0.04$, $t = -0.27$, $p = .787$, $BF_{10} = 1.18$; affective: $\beta = -0.04$, $t = -0.27$, $p = .792$, $BF_{10} = 1.61$). Bayesian analysis indicated anecdotal evidence for the absence of an association for the ChT subscale, and also anecdotal evidence of an association for the AUT subscale and both BES subscales. Although the FFT and ASC TEAQ subscale did not reach significance as a predictor, Bayesian analysis revealed decisive and strong evidence, respectively, supporting their association with the NRS Other ratings. The variable group (autistic vs non-autistic) also did not significantly predict greater NRS Other scores ($\beta = -0.10$, $SE = 0.29$, $t = -0.34$, $p = .738$).

5.4.2. Group Comparisons in Touch and Empathy Questionnaire Scores

Regarding the TEAQ, for the FFT subscale scores results revealed significantly lower values for the autistic group ($M = 2.86$, $SD = 0.83$) compared to the non-autistic group ($M = 3.76$, $SD = 0.79$), $t(84) = -5.12$, $p < .001$, Cohen's $d = -1.11$, $BF_{10} = 7584.80$. The ASC subscale scores were also significantly lower in the autistic group ($M = 2.40$, $SD = 0.75$) compared to the non-autistic group ($M = 3.27$, $SD = 1.51$), $t(84) = -4.22$, $p < .001$, Cohen's $d = -0.91$, $BF_{10} = 341.62$. Similarly, the AUT subscale scores results revealed significantly lower values for the autistic group ($M = 2.64$, $SD = 0.78$) compared to the non-autistic group ($M = 3.19$, $SD = 0.79$), $t(84) = -3.21$, $p = .002$, Cohen's $d = -0.69$, $BF_{10} = 17.50$. Both FFT and ASC indicate decisive and AUT indicates strong evidence of differences between groups. No significant differences were found between groups for the ChT subscale ($t(84) = -1.01$, $p = .315$, Cohen's $d = -0.22$, $BF_{10} = 0.35$), indicating anecdotal evidence of no differences between groups.

For the BES Cognitive Empathy scores, the autistic group ($M = 3.50$, $SD = 0.40$) exhibited significantly lower scores than the non-autistic group ($M = 4.16$, $SD = 0.44$), $t(84) = -7.29$, $p < .001$, Cohen's $d = -1.58$, $BF_{10} = 47550000$. Similarly, the BES Affective Empathy scores were significantly lower in autistic participants ($M = 3.19$, $SD = 0.43$) compared to non-autistic participants ($M = 3.66$, $SD = 0.59$), $t(84) = -4.28$, $p < .001$, Cohen's $d = -0.93$, $BF_{10} = 412.74$. Both indicate decisive evidence of differences between groups.

5.4.3. Experimental Task Results

For the NRS Self and Others, no significant differences were found between groups ($t(84) = -0.06$, $p = .949$, Cohen's $d = -0.01$, $BF_{10} = 0.23$ and $t(84) = -1.89$, $p = .063$, Cohen's $d = -0.41$, $BF_{10} = 1.06$, respectively). The Bayes factor indicates substantial evidence of no differences between groups in the NRS Self, while indicates anecdotal evidence of differences between groups in the NRS Other.

For the NRS Self ratings, results revealed a significant main effect of skin location [$F(3.10,216.62) = 6.08$, $p < .001$, $\eta_p^2 = .08$, $BF_{10} = 443.07$], indicating decisive evidence for the effect. Post-hoc paired comparisons showed significant differences between the ventral forearm and the back [$t(70) = -3.26$, $p = .010$, Cohen's $d = -0.28$], the dorsal forearm and the back [$t(70) = -4.20$, $p < .001$, Cohen's $d = -0.36$], the upper arm and the back [$t(70) = -4.25$, $p < .001$, Cohen's $d = -0.37$], and the hand and the back [$t(70) = -3.27$, $p = .010$, Cohen's $d = -0.28$], with higher ratings for the back condition. No significant differences were observed for the other skin locations. There was also a significant main effect of speed of stroking [$F(1.57,110.21) = 18.65$, $p < .001$, $\eta_p^2 = .21$, $BF_{10} = 35156.16$], indicating decisive evidence for the effect. Post-hoc paired comparisons showed significant differences between the condition static vs slow [$t(70) = -6.02$, $p < .001$, Cohen's $d = -0.50$], static vs fast [$t(70) = -2.11$, $p = .037$, Cohen's $d = -0.18$], and slow vs fast [$t(70) = 3.91$, $p < .001$, Cohen's $d = 0.33$], with higher ratings for slow and fast conditions compared to the static condition and higher ratings for the slow condition compared to the fast condition. Furthermore, there is a significant main effect of sex [$F(1,70) = 6.17$, $p = .015$, $\eta_p^2 = .08$, $BF_{10} = 2.56$] with male participants giving higher ratings [$t(85) = 2.48$, $p = .015$, Cohen's $d = 0.36$], and indicating anecdotal evidence for the effect. No significant differences were observed for group [$F(1,70) = 0.34$, $p = .564$, $\eta_p^2 = .005$, $BF_{10} = 0.19$], indicating substantial evidence for no effects. A significant interaction effect also emerged between speed and skin location [$F(5.89,412.38) = 12.96$, $p < .001$, $\eta_p^2 = .16$, $BF_{10} = 16180000$], indicating decisive evidence for the effect. Finally, a significant interaction effect emerged between speed, skin location and group [$F(5.89,412.38) = 2.22$, $p = .042$, $\eta_p^2 = .03$, $BF_{10} = 3165000$], indicating decisive evidence for the effect. The post-hoc paired comparisons for these interaction effects are provided in Appendix C.

For the NRS Other ratings, results also revealed a significant main effect of skin location [$F(2.81,199.22) = 12.86$, $p < .001$, $\eta_p^2 = .15$, $BF_{10} = 32260000$], indicating decisive evidence for the effect. Post-hoc paired comparisons showed significant differences between the ventral forearm and the back [$t(71) = -5.99$, $p < .001$, Cohen's $d = -0.49$], the dorsal forearm and the back [$t(71) = -6.12$, $p < .001$, Cohen's $d = -0.50$], the upper arm and the back [$t(71) = -5.01$, $p < .001$, Cohen's $d = -0.41$], and the hand and the back [$t(71) = -5.11$, $p < .001$, Cohen's $d = -0.42$], with higher ratings for the back

condition. No significant differences were observed for the other skin locations. There was also a significant main effect of speed of stroking [$F(1.64,116.56) = 8.16$, $p = .001$, $\eta_p^2 = .10$, $BF_{10} = 47.22$], indicating very strong evidence for the effect. Post-hoc paired comparisons showed significant differences between the condition static vs slow [$t(71) = -3.62$, $p = .001$, Cohen's $d = -0.30$], and slow vs fast [$t(71) = 3.37$, $p = .002$, Cohen's $d = 0.28$], with higher ratings for the slow condition. No significant differences were observed for group [$F(1,71) = 3.42$, $p = .069$, $\eta_p^2 = .05$, $BF_{10} = 1.34$], and sex [$F(1,71) = 1.79$, $p = .185$, $\eta_p^2 = .03$, $BF_{10} = 0.78$], indicating anecdotal evidence for the effect of group and anecdotal evidence for no effect of sex. A significant interaction effect also emerged between speed and skin location [$F(5.95,422,59) = 14.01$, $p < .001$, $\eta_p^2 = .17$, $BF_{10} = 1500000000$], providing decisive evidence for the effect. The post-hoc paired comparisons for this interaction are provided in Appendix C.

Additional analyses exploring within-group variability in the ASD sample are reported in Appendix C, including sex differences and associations between questionnaire measures (TEAQ, BES, CBCL), intellectual coefficient, and touch perception outcomes (NRS Self and NRS Other).

5.4.4. Regression Analysis

For both NRS Self and Other, at the dorsal forearm and the upper arm, a quadratic regression term explained significantly more of the variance than a linear regression term (dorsal forearm – Self: linear $t = 1.81$, $p = .072$ and quadratic $t = -2.39$, $p = .018$; Other: linear $t = 1.21$, $p = .229$ and quadratic $t = -2.63$, $p = .009$; upper arm – Self: linear $t = 1.78$, $p = .077$ and quadratic $t = -5.31$, $p < .001$; Other: linear $t = 1.67$, $p = .098$ and quadratic $t = -4.91$, $p < .001$). On the back, for the NRS Self, the same pattern was observed (linear $t = 1.56$, $p = .121$; quadratic $t = -2.46$, $p = .015$). However, for the NRS Other, both the linear ($t = 2.61$, $p = .010$) and the quadratic ($t = -3.36$, $p < .001$) terms were significant. On the ventral forearm, for the NRS Self, both the linear ($t = 2.13$, $p = .034$) and the quadratic ($t = -3.68$, $p < .001$) terms were significant, while for the NRS Other the quadratic regression term ($t = -3.66$, $p < .001$) explained significantly more of the variance than a linear regression term ($t = 1.58$, $p = .116$). Finally, on the hand, for both NRS Self and Other, a linear regression term explained significantly more of the variance than a quadratic regression term (Self: linear $t = -4.91$, $p < .001$ and quadratic $t = -0.09$, $p = .925$; Other: linear $t = -5.90$, $p < .001$ and quadratic $t = 0.81$, $p = .418$).

5.4.4.1. Full Model. For both NRS Self and Other, it was determined whether the quadratic terms describing velocity for each CT innervated location were significantly different to those of the hand. For the NRS Self, for hairy skin sites, the quadratic term was significantly more negative (more

pronounced inverted U) compared to the hand in the upper arm (t = -3.73, p < .001) and ventral forearm (t = -2.51, p = .012). The back (t = -1.69, p = .091) and dorsal forearm (t = -1.51, p = .131) sites did not show a significantly different curvature from the hand in this model. No main group effect was found (t = 0.40, p = .688), indicating that the overall ratings were similar between the control group and the ASD group. The interaction between the group and the quadratic velocity term was also not significant (t = -1.71, p = .088), reinforcing that the curvilinear response pattern is comparable between the two groups in this touch dimension.

For the NRS Other, the ratings for each of the 4 CT-innervated locations, the quadratic term was significantly more negative (steeper inverted U) compared with the hand (back: t = -2.89, p = .004; dorsal forearm: t = -2.20, p = .028; ventral forearm: t = -3.16, p = .002; upper arm: t = -3.84, p < .001). Additionally, we observed a main effect of the group (t = 2.03, p = .046), indicating that the control group rated globally higher ratings than the ASD group. However, the interaction between the group and the quadratic velocity term was not significant (t = -1.77, p = .077), suggesting that the curve response pattern (preference for CT-targeted touch) is relatively preserved in both groups.

5.5. Discussion

The present study aimed to evaluate how autistic adolescents and young adults perceive vicarious social touch compared to their non-autistic peers. Specifically, we examined valence ratings (self- and other-oriented) during the observation of short video clips depicting someone being touched at three speeds (static, CT-optimal, and fast) and at five distinct skin locations (back, upper arm, ventral forearm, dorsal forearm, and palm). We further explored how these valence ratings relate to individual differences in empathy and attitudes toward touch. Results showed no significant group differences in participants' ratings of pleasantness and willingness (NRS Self and Other), although a three-way interaction between speed, skin location, and group emerged for the NRS Self. Moreover, pleasantness and willingness ratings (NRS Self and Other) appear to be modulated by both speed and skin location, with CT-optimal stroking and touch delivered to the back rated as most pleasant across groups. Sex differences also emerged for NRS Self ratings, with male participants rating observed touch as significantly more pleasant than females did, regardless of group. Complementary regression analyses further showed that pleasantness ratings followed a characteristic inverted-U relationship with stroking velocity at CT-innervated (hairy) skin sites, whereas ratings for the palm were better captured by a linear function. Importantly, this velocity-dependent curvature did not significantly differ between groups, suggesting a preserved CT-specific tuning profile in autistic and non-autistic participants. In addition, findings suggest that NRS Self ratings were

positively correlated with attitudes toward self-care (TEAQ ASC), while NRS Other ratings were positively correlated with interpersonal touch and self-care attitudes (TEAQ FFT and ASC) in the autistic group. No significant associations were observed in the non-autistic group. As expected, autistic participants reported significantly lower scores on measures of interpersonal touch and self-care (TEAQ FFT, AUT, and ASC), as well as on both cognitive and affective empathy (BES).

Contrary to our initial hypotheses, autistic and non-autistic participants did not significantly differ in the touch pleasantness for the actors in the videos (NRS Other), as well as in the willingness to receive a similar touch (NRS Self), suggesting that autistic and non-autistic adolescents and young adults perceived vicarious touch similarly at a global level. Importantly, Bayesian analyses provided additional support for these null effects, indicating moderate evidence in favour of the null hypothesis for several comparisons, rather than merely an absence of statistically significant differences. These findings contrast with previous studies reporting reduced pleasantness ratings or increased defensive responses to social touch in autism (Baranek et al., 2006; Cascio et al., 2016; Foss-Feig et al., 2012; Kaiser et al., 2016), but are in line with Haggarty et al. (2021a), who also found no differences in observed touch ratings between autistic and non-autistic children despite parental reports of heightened somatosensory sensitivities in the autistic group. As Haggarty and colleagues noted, this may reflect that observing touch does not trigger the same sensory discomfort as direct tactile stimulation and instead draws more heavily on cognitive appraisal and social interpretation processes. In this context, group differences may be attenuated, particularly in autistic individuals who have adapted to interpreting social touch cues in everyday life (Haggarty et al., 2021a),. The nature of the task could be another possible explanation, since participants were observing touch rather than directly experiencing it, the sensory demands were likely lower, which may have reduced potential differences between groups. Additionally, the sample may include autistic individuals with fewer sensory atypicalities, above-average cognitive abilities, or greater adaptation to social touch contexts, which could have contributed to the lack of group-level effects. Together, the non-significant results and Bayesian evidence for the null hypothesis strengthens the interpretation that group similarities are unlikely to be solely due to insufficient statistical power and instead reflect genuine similarity between groups in overall vicarious touch appraisal. These findings suggest that affective touch differences in autism may be more context-dependent and underscore the need for multi-modal approaches that capture both observed and embodied aspects of touch processing.

Independent of group, significant main effects of stroking speed and skin location were found, aligning with previous literature. As expected, CT-optimal touch was rated as more pleasant than static and fast touch, for both perceived pleasantness of the actor in the video and their own willingness to

receive a similar touch (NRS Other and Self). These variations in ratings across speeds likely correspond to the velocities that optimally activate CT afferents (Ackerley et al., 2014; Löken et al., 2009; Olausson et al., 2016). As also expected, stroking in the back was rated as more pleasant than other body sites, since hairy regions are believed to have dense afferent innervation of CT afferents (Löken et al., 2009; Vallbo et al., 1999). These results replicate previous findings studies using the same stimuli, which also reported a very similar pattern, with higher pleasantness ratings for CT-optimal speed, particularly on the back (Devine et al., 2020; Haggarty et al., 2021a; Pereira et al., 2025; Walker et al., 2017). Overall, these findings reinforce the involvement of the CT system in the affective domain of touch and suggest that the experimental paradigm effectively engaged CT-mediated hedonic processing. These findings are consistent with Butti et al. (2024), who showed that both self- and other-related vicarious touch ratings are selectively tuned to CT-optimal stimulation, despite relying on partially distinct neurocognitive mechanisms. Accordingly, the preserved modulation of both pleasantness and willingness by stroking speed supports the notion that CT-mediated affective signals are robustly engaged during vicarious touch perception, while reinforcing the idea that these two evaluative dimensions - one focusing on the perceived hedonic value for others and the other on personal motivational intent - are related yet distinct.

Our regression analysis revealed that ratings of observed affective touch followed a characteristic inverted-U-shaped relationship with stroking speed at several CT-innervated sites, consistent with patterns described in the broader literature on affective touch. Specifically, quadratic speed terms explained significant variance over and above linear terms at the dorsal forearm and upper arm for both NRS Self and Other, and at the back and ventral forearm for at least one rating dimension, whereas on the hand (glabrous skin) ratings were better described by a linear function. This shape reflects the classic speed-tuning of CT afferents, which fire optimally at intermediate (CT-optimal) speeds and contribute to hedonic experiences of touch (Croy et al., 2016; Crucianelli et al., 2022). At the individual level, similar negative quadratic functions have been shown to reliably capture pleasantness responses to tactile stimulation across skin locations (Crucianelli et al., 2022). In the full model, CT-specific curvatures were significantly more pronounced than for the hand in several comparisons, and although group did not significantly interact with the quadratic term, a main effect of group on NRS Other suggests that autistic participants gave generally lower ratings overall. This pattern indicates that while the core inverted-U profile of velocity tuning is preserved across groups, global hedonic evaluation of observed touch may differ in autism. The inverted-U relationship is considered a hallmark of CT-afferent processing (Croy et al., 2016; Löken et al., 2009) and its modulation by broader socio-emotional traits has been increasingly documented in both

neurotypical and autistic samples (Cascio et al., 2016; Crucianelli et al., 2022; Foss-Feig et al., 2012; Pawling et al., 2024).

However, a significant three-way interaction between speed, skin location, and group was found for the willingness (NRS Self). Although overall affective appraisals of touch did not differ, the pattern of responses across conditions diverged between groups. This interaction may reflect nuanced differences in how autistic people integrate vicarious touch depending on touch features, such as the social salience of the body location and the affective value of the stroking velocity (Cascio et al., 2012; Morrison et al., 2010). Specifically, while neurotypical individuals might show a more uniform preference for CT-optimal speeds across skin sites, the autistic group's responses appear more sensitive to the combination of touch features. This suggests that the 'willingness to receive touch' in autism may be contingent upon the specific interaction between the social salience of the body location (e.g., the perceived intrusiveness of touch to certain areas) and the physical properties of the stimulus (i.e., stroking speed). Thus, although overall ratings were similar between groups, this interaction highlights that autistic individuals may employ distinct evaluative weighing contextual and tactile cues when processing social-tactile scenarios (see Appendix C).

Finally, sex differences also emerged for the willingness ratings (NRS Self), with male participants rating observed touch as significantly more pleasant than females did, independent of group. Although relatively understudied in the context of vicarious affective touch, prior research has shown that females are more likely than males to avoid or report greater discomfort and unpleasantness with unfamiliar or socially ambiguous touch, potentially due to heightened concerns about personal boundaries, gendered expectations and cultural norms, or socialisation processes (Hertenstein et al., 2006; Russo et al., 2020; Schirmer et al., 2022; Suvilehto et al., 2015). From a theoretical perspective, these sex differences may reflect broader differences in social-emotional sensitivity, threat appraisal, and interpretation of interpersonal intent conveyed through touch. These factors may contribute to more conservative evaluations of touch scenarios by females, particularly when the social intent or familiarity is unclear (Russo et al., 2020; Suvilehto et al., 2015). Notably, Schirmer et al. (2022) reported that females tended to perceive touch as more ambiguous and emotionally complex than males, especially in contexts lacking clear relational cues. Together, these results suggest that sex-related differences in vicarious touch perception may arise from differential weighting of affective, contextual and social cues. While the current findings highlight a consistent pattern across groups, further research is needed to clarify the mechanisms underlying these sex differences in vicarious touch perception, particularly across developmental stages and cultural contexts.

Additionally, in the autistic group, pleasantness scores (NRS Other) were positively correlated with positive touch experiences with friends and family (TEAQ FFT subscale), supporting the idea that individuals with more positive interpersonal touch experiences tend to perceive touch as more pleasant (Field, 2001), and suggesting that previous experiences with touch and their emotional responses shape how pleasant they perceive observed touch. Furthermore, the pleasantness scores (NRS Other) and the willingness to receive a touch similar to that observed (NRS Self) were both positively correlated with self-care attitudes (TEAQ ASC subscale), suggesting that individuals who engage and value more self-directed tactile and grooming behaviours may experience both observed and imagined social touch as more rewarding (McGlone et al., 2016). These associations were absent in the non-autistic group, highlighting the importance of individual touch experiences and personal attitudes in modulating social-affective touch processing in autistic individuals.

Group differences were observed in several aspects of tactile experiences, such as interpersonal touch with friends and family (FFT subscale), attitudes toward self-care and grooming (ASC subscale), and attitudes toward unfamiliar touch (AUT subscales). Autistic participants reported fewer positive experiences of interpersonal touch with friends and family, which may reflect heightened or reduced sensitivity to tactile stimuli and difficulties in forming or maintaining close social bonds in which affectionate touch is common (Foss-Feig et al., 2012; Reynolds et al., 2011; Tomchek et al., 2018). Reduced exposure to positive social touch could contribute to a lower affective value to touch in general (Cascio et al., 2019). Autistic individuals also showed lower scores on positive attitude to self-care, which may suggest reduced engagement in self-directed tactile behaviours (e.g., grooming or body care). This can potentially reflect difficulties in adaptive functioning, such as self-care and independence, that are commonly observed in this population (Varghese & Naomi, 2024). Finally, the autistic group revealed lower positive attitude to unfamiliar touch, which may suggest sensory sensitivity or discomfort in unpredictable social contexts consistent with DSM-5 criteria and prior studies (American Psychiatric Association, 2022; Tomchek et al., 2018). Group differences were also observed in both cognitive and affective empathy (BES subscales). Consistent with previous studies (Mathersul et al., 2013; McIntosh et al., 2006; Minio-Paluello et al., 2009; Shamay-Tsoory et al., 2002), autistic participants scored significantly lower on both empathy dimensions compared to non-autistic participants. While reduced cognitive empathy in autism is well documented, the finding of lower affective empathy is more controversial, as some research reports intact or even heightened affective empathy in certain contexts (Bons et al., 2013; Deschamps et al., 2014; Dziobek et al., 2008; Hadjikhani et al., 2014; Rueda et al., 2015; Schwenck et al., 2012). Discrepancies in the literature may arise from differences in how affective

empathy is conceptualised and measured, the social relevance of stimuli, or the role of alexithymia (a condition that often co-occurs with autism, characterised by a diminished ability to identify and describe others' emotions, which can lead to reduced empathy and difficulties in recognising those emotions) (Bird & Cook, 2013). In our study, the lower affective empathy scores could reflect challenges in recognising or appropriately regulating emotional responses to others, potentially influenced by the abstract nature of the questionnaire and the absence of direct emotional cues. This supports the idea that empathic processes are disrupted in autistic people, with differences particularly pronounced in cognitive empathy.

Some limitations should be acknowledged. The inclusion criteria and design of the experimental task may have caused a bias in a sample of autistic individuals with fewer or less severe sensory difficulties, limiting the generalisability of the findings across the autism spectrum. Additionally, the sample consisted of adolescents and young adults, a period that encompasses substantial developmental changes (maturation of social, emotional, and sensory processing); this age-related variability may have contributed to individual differences in vicarious touch ratings. Future research should examine broader age ranges and consider the potential influence of developmental trajectories. Furthermore, although the questionnaires used provide valuable insight into subjective experience, including parent-reported measures or qualitative accounts of touch experiences could yield a more detailed and ecologically account of affective touch perception. Another limitation concerns the definition of the control group based solely on the absence of a formal ASD diagnosis. As autistic traits vary dimensionally in the general population, subclinical traits or undiagnosed ASD cannot be excluded. Future research should include a standardised measure of autistic traits in the comparison group to quantify such variability. Finally, future research should integrate neurophysiological or neuroimaging measures to capture implicit, embodied responses to social touch and elucidate the underlying neural mechanisms involved in vicarious tactile processing, while also providing clarity on how these mechanisms may guide the development of applied interventions. In this regard, although the present findings should be interpreted with caution given the characteristics of the current sample and the observational nature of the task, the preserved sensitivity to CT-optimal touch observed at the group level suggests that interventions incorporating gentle, socially meaningful touch, or even vicarious representations of such touch, may remain accessible and potentially beneficial for autistic adolescents and young adults when appropriately contextualised. For instance, social touch-based interventions, sensory integration therapies, or emotion-regulation programmes may benefit from incorporating graded exposure to affective touch cues while taking into account individual touch experiences, self-care attitudes, and comfort with unfamiliar touch. Moreover, the observed associations between vicarious touch pleasantness/willingness, empathy, and touch-related experiences

highlight the potential value of personalised approaches that integrate sensory, affective, and social-cognitive dimensions when designing interventions for autistic individuals.

5.5.1. Conclusion

Overall, our findings suggest that while autistic adolescents and young adults did not differ significantly from their non-autistic peers in their overall ratings of observed social touch, they showed distinct patterns of empathy and touch-related experiences. The interaction between pleasantness/willingness ratings and speed and skin location reinforces the role of CT-optimal touch in affective processing, and the observed associations with experiences and attitudes toward touch further highlight the importance of interpersonal touch in shaping social touch perception. Together, these findings highlight the complexity and individual variability of CT-targeted touch perception in autistic individuals and the need for a multidimensional approach to understanding tactile perception in autism integrating sensory, cognitive, affective, and developmental factors to better understand its role in social interaction.

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CHAPTER 6

General Discussion

The present dissertation aimed to expand the current knowledge about the CT system by addressing specific gaps in the literature regarding how CT-targeted stimulation is evaluated and processed across subjective, behavioural, and neural levels. More specifically, we aimed to develop and validate the European Portuguese version of the TEAQ to establish a foundational tool to capture interindividual variability in tactile experiences (Chapter 2). Aiming to grasp more comprehensively the mechanisms underlying the processing of CT-targeted stimulation, the first empirical study investigated the neural processing of CT-targeted stimulation in neurotypical adults (Chapter 3). The following studies extended this investigation to the perception of vicarious affective touch. Specifically, we examined how neurotypical adults evaluate and process observed CT-targeted touch (Chapter 4), and how these vicarious mechanisms are altered in individuals with ASD (Chapter 5). This work was grounded in the social touch hypothesis (McGlone et al., 2014; Morrison, 2016), which provides the theoretical framework for interpreting CT afferents as specialised system for the affective and affiliative dimensions of touch. The present chapter summarises the main findings of these studies, integrating them into the broader literature on affective touch, discussing their methodological limitations, directions for future research, and practical implications.

6.1. Subjective Experience of CT-Targeted Touch

The findings across this dissertation suggest that affective touch processing emerges from the dynamic interaction between bottom-up sensory input and top-down cognitive and affective processes. The perception of affective touch appears to be related to the integration of the sensory information from touch with previous experiences and expectations. While Aβ provide perceptual precision, CT fibres engage areas like the posterior insular and cingulate cortex, underpinning affective valuation and the motivational relevance of touch (McGlone et al., 2014; Morrison et al., 2010). In this sense, the integration of these systems enables the translation of physical contact into a socially meaningful and emotionally rewarding experience.

6.1.1. Sensitivity to CT-Optimal Speeds Across Contexts and the Role of Skin Location

The evidence provided by this work converges on the idea that the hedonic value of touch is inherently associated with its speed, and such preference remains robust whether the stimulus is directly felt or vicariously observed. The results showed that the observation of CT-optimal touch was consistently

rated as more pleasant and associated with greater willingness to be touched than either static or fast touch conditions. This replicates prior research showing the hedonic preference for CT-optimal velocities during observed touch (Devine et al., 2020; Haggarty et al., 2021a, 2021b; Walker et al., 2017). In the same vein, using direct tactile stimulation reinforces this subjective preference for affective over discriminative touch, with stroking stimulation also rated as significantly more pleasant than vibrotactile stimulation. These findings were in line with previous literature, which showed that CT-optimal touch was rated as significantly more pleasant than non-CT-optimal touch (Ackerley et al., 2014; Essick et al., 1999, 2010; Löken et al., 2009) and also aligned with prior findings emphasising the emotional significance of CT-mediated touch (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2002, 2008; Walker et al., 2022). This evidence reinforces the idea that the speed and temporal pattern of touch are central determinants of its affective evaluation, whether the touch is felt in the first person or observed. This consistency across direct and vicarious contexts can be explained within a framework of predictive processing, in which prior experiences with touch contribute to the formation of expectations regarding what is pleasant or socially relevant. CT-optimal velocities may be more closely related to these expectations, thereby resulting in a more positive evaluation. Furthermore, from an embodied simulation perspective, the fact that observation of CT-optimal touch elicits similar hedonic ratings to direct touch suggests a sensory-affective resonance that allows to internalise the rewarding nature of social contact even without direct physical touch.

Furthermore, skin location emerged as a key factor in modulating perceived pleasantness and willingness to receive touch. Across both studies using vicarious CT-targeted touch, the back was consistently rated as the most pleasant touch location. This finding aligns with evidence suggesting that CT afferents are more densely innervated in proximal hairy skin regions, such as the back, than in distal or glabrous skin, like the palm (Kumazawa & Perl, 1977; Vallbo et al., 1999), and that there are perception variations of pleasure of CT-targeted touch in different skin areas of the body, with higher pleasantness ratings for touch performed on the back (Devine et al., 2020; Haggarty et al., 2021a; Walker et al., 2017). The participants' subjective ratings appear to mirror this anatomical distribution, suggesting that the brain's "pleasantness map" is intrinsically linked to the peripheral availability of CT afferents.

6.1.2. Individual Differences in Touch Attitudes and Experiences

The findings of this work suggest that affective touch appears to be significantly shaped by top-down individual differences. The validation of the European Portuguese version of the TEAQ provided a robust, culturally sensitive psychometric instrument for assessing individual differences in touch-related

experiences and attitudes. The psychometric evaluation confirmed the original six-factor structure and demonstrated good internal consistency, reliability, and construct validity. By integrating this psychometric tool into our experimental studies, we were able to demonstrate that subjective evaluations of touch are significantly modulated by personal experiences and attitudes towards touch. Across all experiments, the TEAQ emerged as a meaningful tool to contextualise individual differences in affective touch processing.

Regardless of whether the focus was on direct and vicarious CT-targeted touch, participants with more positive self-reported experiences and attitudes toward touch, particularly on subscales related to intimate touch, tended to rate CT-optimal touch as more pleasant and to be more willing to engage with it. This pattern supports a predictive processing perspective, suggesting that differences in tactile history and attitudes may be related to differences in prior expectations of touch. These expectations could potentially impact the way information from touch is interpreted, influencing both subjective evaluations and neural responses. Consequently, individuals who have a more positive tactile history may have a bias that associates touch with safety and rewarding experiences, whereas those with more restricted or defensive profiles, as observed in the ASD group, may have a different interpretation for the same sensory input based on their tactile experiences.

Additionally, we found significant sex differences within the TEAQ. Female participants reported more positive touch experiences but also higher caution toward unfamiliar contact. These findings are consistent with theories of emotional socialisation, which suggests that gendered socialisation shape how individuals perceive and use affective touch as a means of expressing closeness, in which females are generally encouraged to engage in emotional expression and physical affection behaviours in close relationships (Brody & Hall, 2008; Floyd, 2006), while simultaneously they are taught to be more vigilant or cautious about being touch by unfamiliar others due to increase social norms around personal safety and bodily autonomy (Hertenstein et al., 2006; LaFrance & Vial, 2016).

Furthermore, this study is consistent with the view that affective and social touch are shaped not only by somatosensory factors but also by the quantity and variety of interpersonal experiences and individual attitudes (McGlone et al., 2014; Morrison, 2016). This aligns with models that view affective touch as a key modality for emotional regulation and attachment, in which early tactile experiences shape neural and psychological sensitivity to social contact across the lifespan (Cascio et al., 2019; Walker et al., 2017). The reported results highlight the importance of considering personal tactile history when investigating variability in how individuals perceive and respond to touch.

6.2. Neurophysiological Signatures of Direct and Vicarious CT-Targeted Touch

The neurophysiological evidence of this dissertation complements the behavioural data by providing a neural basis for affective touch processing. While the previous section focused on the feelings that the participants experienced and their reports, this section examines the brain's responses to CT-targeted touch, both when it is felt directly and when it is observed. By using EEG, we were able to identify specific neural markers that distinguish affective touch from other types of stimulation.

6.2.1. Oscillatory Dynamics

A central and consistent neurophysiological finding across this dissertation was the reduction in beta power during CT-optimal touch, observed both during direct tactile stimulation and vicarious observation. Beta desynchronisation, particularly over sensorimotor areas, is a widely documented marker of somatosensory and motor processing and attentional engagement, sensitive to the emotional load of the stimuli (Jessen & Kotz, 2011; Pfurtscheller & Lopes da Silva, 1999). Finding reduced beta power potentially reflects the brain's engagement with emotionally salient information (Charidza & Gillmeister, 2022) and may serve as a relevant neural index of CT-targeted touch processing.

The functional role of beta desynchronisation has been extended to social perception and action observation, suggesting shared neural substrates for performing and observing actions (Hari & Kujala, 2009). In this context of affective touch, beta suppression may reflect both the cortical processing of tactile inputs and the embodiment and empathic simulation of observed touch. From the perspective of embodied simulation, these shared neural dynamics observed during direct and vicarious touch suggest that the observation of touch engages internalised representations of sensorimotor experience, similar to those involved during direct experience, allowing individuals to understand the experience of touch on another onto their own bodily state. This interpretation could explain the overlap observed between the direct and vicarious conditions of touch in our studies, particularly in the consistent beta desynchronisation observed between the conditions. These findings highlight the hypothesis that CT-targeted touch engages complex brain systems beyond primary somatosensory regions, including mirror-like mechanisms that integrate sensory, motor, and affective components (Bufalari & Ionta, 2013; Ebisch et al., 2011; Lee Masson et al., 2018; Morrison et al., 2011). In this sense, beta desynchronisation might not only be related to sensory processing but also, at least in part, to the processing of affective and social content associated with touch and thus connect somatosensory processing with socio-cognitive processing. In the same vein, previous research in this area has suggested this mirror-like type of response (Bolognini et al., 2014; Keysers et al., 2004, 2010; Morrison et al., 2011; Schaefer et al., 2005,

2009, 2012). These results position beta power as a key neural index of CT-targeted touch processing, responsive to both first-hand and vicarious experiences and sensitive to individual affective characteristics.

In addition to beta modulations, alpha/mu activity also revealed significant, however more context-dependent, patterns of activation. In direct CT-targeted touch, receiving CT-optimal stroking stimulation was related to reduced alpha/mu in central/Rolandic regions compared to vibrotactile stimulation. Posterior alpha suppression is typically associated with increased sensory engagement and cortical excitability (Griffiths et al., 2019; Jensen & Mazaheri, 2010; Klimesch, 2012; Pfurtscheller & Lopes da Silva, 1999; Salamanca-giron et al., 2021), supporting the idea that affective touch elicits stronger sensorimotor activation than neutral or discriminative stimuli. However, during vicarious touch, we only found reduced alpha power spectral density in exploratory topographical analysis for both dynamic conditions (slow and fast) compared to the static condition over parieto-occipital regions, but the effects of speed did not reach the significance levels. However, as the stroking stimulus is dynamic and the vibration is static (in the study with direct stimulation), some of these differences may also reflect these differences in stimulus dynamics rather than touch type alone. This absence of alpha modulation during observed touch may reflect differences in sensorimotor resonance when touch is only observed rather than physically experienced, or it may indicate that all touch conditions, including static, were perceived as socially salient to some extent, weakening condition-specific effects. Complementary to this, we found increased midfrontal theta power during vicarious CT-optimal touch, which has also been observed in response to emotionally salient stimuli (Knyazev et al., 2009; Symons et al., 2016).

Overall, the findings from neurophysiological studies converge to support the idea that CT-optimal touch engages a distinct neural signature. This response is characterised by desynchronisation in the alpha and beta bands, and synchronisation of theta activity. The reported results reflect the sensorimotor, attentional, and emotional engagement of CT-targeted touch while supporting its classification as a sensory modality that is rich in social and affective aspects. Together, these findings suggest that affective touch engages distributed neural systems that support sensorimotor and socio-affective processing during both direct and observed touch.

6.2.2. Global Brain States and Temporal Dynamics

Beyond oscillatory power, this work revealed that affective touch triggers a broader shift in global brain dynamics. Microstate analyses showed a significantly reduced prevalence of class A and an increased prevalence of classes B and D during CT-targeted stroking. Given that class A has been linked to auditory processing and arousability, while classes B and D are associated with attention and visual

integration processes (Schiller et al., 2023), these results suggest a reconfiguration of global brain dynamics, potentially reflecting differences in attentional engagement and arousal. These changes could reflect the dual function of affective touch in promoting cognitive sensory processing while simultaneously eliciting calming, socially affiliative effects (Croy et al., 2022; Walker et al., 2022).

Furthermore, some markers, such as the LPP, did not show significant modulation. The LPP is typically linked to sustained attention and the emotional significance of stimuli (Nowparast Rostami et al., 2016; Pollux, 2016). However, unlike previous findings reporting heightened LPP responses to affective touch imagery (e.g., Schirmer & McGlone, 2019), our study did not replicate this effect possibly due to the dynamic nature of our stimuli.

Despite the lack of LPP modulation, the overall pattern of results suggests that the CT system does not merely activate isolated regions. Instead, it shifts the brain into a state of heightened social receptivity, dynamically modulating how sensory information is integrated within a predictive processing framework. By reconfiguring these global states, the brain may be prioritising socially salient information, allowing for a more profound and sustained attunement to the presence and intentions of others.

6.3. Affective Touch in Atypical Development: The Case of ASD

The findings of this dissertation reveal a differentiated pattern in how individuals with ASD experience affective touch. In global ratings, participants with ASD did not differ from neurotypical participants in touch pleasantness or willingness to be touched. However, a significant three-way interaction among stroking speed, skin location, and group was observed for willingness to be touched, indicating that group differences appeared only across specific conditions. Both groups showed lower willingness for static touch and touch delivered to the hand compared to CT-optimal stimulation on proximal body sites (e.g., forearm or back), but individuals with ASD exhibited a different pattern in how these stimulus features were integrated, with some body locations showing reduced differentiation between CT-optimal and non-optimal touch.

These findings support that, although general perceptual sensitivity to the affective dimensions of affective touch may be preserved, the integration of stimulus features such as speed and body location in self-relevant evaluations and interpretations may differ in ASD, based on individual or neurodevelopmental factors (Cascio et al., 2016; Kaiser et al., 2016). Moreover, these findings may therefore reflect differences in how stimulus features are integrated when evaluating social touch in ASD. This interpretation is also consistent with a proposal that individuals with ASD have atypical weighting of the precision of sensory versus prior information (Pellicano & Burr, 2012).

Individuals with ASD presented significantly lower scores on several TEAQ subscales, especially those related to social and unfamiliar touch, compared to neurotypical individuals, reflecting more restricted or defensive tactile profiles. These individual differences in tactile experiences and attitudes may also be relevant for understanding broader socio-affective traits, such as empathy, which are known to be associated with how individuals perceive and respond to social touch (Morrison et al., 2011; Schaefer et al., 2012). Additionally, participants with ASD scored significantly lower than neurotypical controls on both cognitive and affective empathy, consistent with previous studies (Mathersul et al., 2013; McIntosh et al., 2006; Minio-Paluello et al., 2009; Shamay-Tsoory et al., 2002). Although empathy scores did not directly predict participants' ratings of vicarious touch, their inclusion provided relevant context for understanding group differences in socio-affective functioning.

Taken together, these findings offer evidence that both the physical properties of observed touch, namely stroking speed and skin location, and individual traits related to tactile and socio-affective experience, shape the perception of affective touch. The convergence of responses across neurotypical and individuals with ASD, particularly the general preference for CT-optimal speeds and touch to proximal body sites like the back, points to a shared sensitivity to the affective qualities of social touch. However, the differences observed in empathy and experiences and attitudes towards touch within the ASD group suggest that individual differences in socio-emotional functioning modulate how contextual features of touch are processed and evaluated. By integrating behavioural and psychometric data across diverse populations, this body of work highlights the importance of considering both stimulus properties and individual differences in understanding social touch perception.

6.3.1. Implications for the Social Touch Hypothesis in Neurodiversity

The evidence presented here suggests that the social touch hypothesis (McGlone et al., 2014; Morrison et al., 2010; Olausson et al., 2010) provides a useful framework, and that adding nuance may help it better capture neurodivergent experiences. Our results indicate that the "social deficit" often associated with individuals with ASD (Lin et al., 2022) is not necessarily an inability to feel pleasure from tactile interactions but a distinct method of integrating sensory and social perceptions. If the brain does not automatically filter touch through social priors (Pellicano & Burr, 2012), it may result in sensory overload or social confusion even if the sensation of the physical touch is pleasant. This shifts the emphasis from a "deficit model," which implies that there is an inherent impairment, to a "divergence model" (Milton, 2012), where information is prioritised differently. In light of the fact that individuals with ASD have greater attention towards the physical properties of touch, this may suggest that social

interaction using touch requires being much more explicit rather than relying on unspoken social conventions. In conclusion, while the results show the potential of the CT system to remain a strong force for social bonding in the context of neurodiversity, we must acknowledge how the divergent brain processes the incoming sensory information along with the social environment.

6.4. Affective Touch Processing: Interactions Between Bottom-Up and Top-Down Mechanisms

The patterns that have emerged from the behavioural, psychometric, and neurophysiological findings of this dissertation converge toward a common underlying process, in which affective touch processing emerges from the dynamic interaction between bottom-up sensory input and top-down cognitive and affective processes. Rather than being a purely sensory experience, the perception of affective touch appears to be related to the integration of the sensory information from touch with previous experiences and expectations, as well as socio-emotional factors. This integrative view is supported by the present findings, which show consistent neural signatures for both direct and vicarious touch, as well as the effects of individual differences in tactile experiences and attitudes, highlighting that both stimulus properties and personal history shape affective touch processing. In this sense, the experience of affective touch can be conceptualised as a dynamic interface between social cognition and sensory embodiment, enabling the translation of physical sensations into emotional meaning and interpersonal comprehension. The findings across the four studies could be framed within a neurocognitive model that combines embodied simulation and predictive processing principles.

According to the embodied simulation perspective (Gallese, 2005; Morrison et al., 2010), CT-optimal touch also functions as a mechanism of social understanding. This embodied simulation mechanism engages neural systems that enable the internal representation of other peoples' mental and physical states, as evidenced by neural responses across direct and vicarious conditions in the present work. Observing others being touched can activate the observer's own somatosensory and affective networks, particularly within the individual to internally simulate and infer the emotional meaning of the tactile event. The hypothesis that sensorimotor resonance processes underlie the social meaning of touch and enable people to 'feel' others' sensations through shared sensorimotor representations (Bufalari & Ionta, 2013; Keysers et al., 2010) is supported by the consistent beta desynchronisation observed across our studies. This process links self- and other-related bodily states, supporting empathy, connection, and prosocial behaviour.

Complementarily, from a predictive processing perspective (Friston, 2010; Kilner et al., 2007), the CT system may contribute to minimising prediction errors regarding social and affective states. Affective touch provides continuous signals that update prior expectations about incoming sensory information, including tactile and affective signals. This is therefore experienced through the minimisation of prediction errors between expected and actual sensory input, shaped by previous experiences and learned associations of safety, affiliation, and reward. Within this framework, atypical sensory prediction mechanisms, as often observed in ASD (Pellicano & Burr, 2012), could explain why individuals with ASD show differences in contextual integration of affective touch, despite intact hedonic perception.

This integrative framework provides a lens through which to interpret the behavioural, psychometric, and electrophysiological findings reported in this dissertation. These two perspectives suggest that CT-targeted touch acts as a bidirectional regulatory system: bottom-up, via embodied resonance in CT afferents and associated cortical networks, and top-down, through predictive mechanisms that shape how social and emotional cues are anticipated and interpreted. The interaction between oscillatory markers (beta, alpha, and theta bands) and behavioural data observed in this dissertation supports this dual-process view. It also highlights how altered calibration between sensory evidence and socio-emotional priors may explain individual variability in affective touch processing, and offers a conceptual bridge between neural oscillatory mechanisms, subjective experience, and social cognition.

6.5. Limitations and Future Directions

This section focuses on the limitations of the present dissertation as well as the future directions for research concerning affective touch and CT-targeted stimulation. Despite the insights provided by this work, several methodological limitations should be acknowledged. First, from a psychometric perspective, although the validation of the self-report instrument on tactile experiences and attitudes towards touch (TEAQ) provided novel data, its applicability to other populations and settings remains to be established. Future work should aim to replicate and extend this validation in different countries and cultural backgrounds to ensure generalisation of the results and enable cross-cultural comparative research. Additionally, future studies could apply this instrument in combination with real assessments of CT-targeted touch, this could provide deeper insights into how individuals perceive and engage with touch in their daily social interactions.

Second, one important limitation shared across two studies included in this dissertation (the experimental studies conducted only with neurotypical participants) is the characteristics of the samples.

Firstly, all participants were university students, individuals generally characterised by high cognitive functioning, which may limit the generalisation of the findings to broader or more diverse populations, particularly those with diverse educational, cognitive, or socio-economic backgrounds (Guerra-Carrillo et al., 2017). On the other hand, in the study in which the sample consists of participants with ASD, only individuals with average to high cognitive functioning were included, not capturing the full heterogeneity of the spectrum, which may similarly limit the generalisation of the findings to the broader ASD population.

Third, although the experimental studies applied a multidimensional approach combining behavioural, and, in some studies, neurophysiological measures, their cross-sectional nature may prevent causal inferences and limit insight into developmental processes. Importantly, neurophysiological data were not collected from the ASD sample (and the neurotypical individuals also present in that study) due to methodological constraints, which prevented to characterise the neural correlates of CT-targeted touch across the different populations. Future research should aim to include such measures in clinical samples, as longitudinal and multimodal designs would be particularly valuable in exploring how early tactile experiences influence socio-affective development and shape later socio-affective outcomes, especially in neurodevelopmental conditions such as ASD.

Fourth, an important limitation in both studies using vicarious touch videos concerns the characteristics of the stimuli. All videos depicted only interactions between Caucasian individuals and featured only mixed-sex (male-female) dyads (i.e., more specifically all videos depicted a Caucasian female person touching a Caucasian male person). This lack of diversity in the stimuli limits the representativeness of the findings and may restrict their generalisability, since participants may respond differently depending on the variability of these factors within themselves and across the individuals represented. Social and cultural factors may influence the perception and evaluation of touch, especially in interpersonal contexts. Future studies should aim to validate more representative datasets and include a wider range of video stimuli that represent diverse ethnicities and sex combinations (e.g., same-sex dyads) to better capture the complexity of social touch perception across different sociocultural backgrounds.

Fifth, in the experimental studies included in this dissertation, both real touch (administered via soft brush) and vicarious touch (through videos) were used to investigate the CT-targeted touch processing. While tactile stimulation allows for precise experimental control and captures key aspects of the somatosensory experience, vicarious paradigms offer an ecological and appropriate alternative, particularly relevant for studying populations such as individuals with ASD, for whom direct social touch can be aversive or overwhelming (American Psychiatric Association, 2022; Tomchek et al., 2018).

However, both approaches have limitations when it comes to fully replicating the complexity of spontaneous social touch interactions as it occurs in natural contexts. Future studies should consider the integration of paradigms based on real interpersonal interactions (both observed or touch exchanges), to strengthen ecological validity and neurophysiological results found.

Finally, although EEG provides excellent temporal resolution, it offers limited spatial resolution. The use of this method in two of our experimental studies does not allow us to measure the activity in deeper subcortical structures and their functional connectivity with cortical regions, due to the low spatial resolution of EEG (Nunez & Srinivasan, 2006). Therefore, while the findings highlight key temporal dynamics and oscillatory mechanisms, future research should consider the use of complementary methods, such as EEG-fMRI, simultaneously. This approach would help clarify the specific cortical and subcortical regions engaged by CT-targeted touch, providing a more comprehensive understanding of its underlying neural mechanisms, and would enable a non-invasive recording of brain activity with both high spatial and temporal resolution (Debener et al., 2006).

6.6. Practical Implications

The findings presented in this dissertation enhanced our understanding of the cognitive processes underlying affective touch. These results can have several practical implications for both clinical practice and broader social contexts. The evidence that CT-targeted touch, whether directly experienced or vicariously observed, elicits greater subjective pleasantness and engages distinct neural mechanisms, highlights its potential as a valuable tool for fostering social connection. Additionally, differences in brain oscillatory patterns associated with affective versus discriminative touch (including modulation of alpha, beta, and theta band activity) provide a neurophysiological basis for understanding how touch shapes attentional and emotional processes. Although our findings in high-functioning individuals with ASD did not reveal marked differences, these mechanisms remain relevant for understanding social-affective processing across populations. These insights may contribute to the development of brain-based interventions (e.g., neurofeedback or sensory therapies) that explore the regulatory effects of touch on affective states and social behaviour.

Furthermore, the results showed that affective touch at the optimal speed for CT receptors does not necessarily have to involve physical contact to generate positive effects, given that vicarious observation of social touch also activates affective and sensory processes. This supports the possibility of using alternative approaches, such as virtual reality or video-based scenarios, that may promote social engagement in individuals with tactile defensiveness or discomfort with direct interpersonal touch. For

clinical groups where touch may be both a cause of discomfort or distress and an opportunity to strengthen social bonds, including these controlled tactile or vicarious experiences in intervention strategies may be particularly beneficial.

The relevance of this type of touch extends beyond neurodevelopmental conditions. The findings from this dissertation, showing that both direct and vicarious affective touch can elicit greater subjective pleasantness and engage distinct neural mechanisms, suggest that interventions grounded in affective touch may also be beneficial for other clinical populations. For example, individuals with chronic pain, post-traumatic stress, or those experiencing high levels of social isolation (e.g., older adults), may also benefit from interventions intended to maximize the affiliative and regulating benefits of gentle touch.

Additionally, the validation of the Portuguese version of the TEAQ provides an important tool for assessing individual differences in touch-related experiences and attitudes. This instrument can serve as a valuable measure for clinicians, educators, and researchers. It could help identify individuals who may benefit from interventions focused on improving comfort with social touch or addressing tendencies toward touch avoidance.

Finally, the findings of this dissertation offer insights that can inform educational and public health strategies by raising awareness of the importance of positive touch experiences for emotional development, mental well-being, and social connection. Given that individual differences in tactile preferences and attitudes influence how touch is perceived and processed, it is essential to foster environments (e.g., clinical, educational, or community) that respect sensory diversity and promote safe, supportive tactile interactions. This is particularly relevant for individuals with neurodevelopmental conditions, such as ASD, who may experience touch in atypical ways (Foss-Feig et al., 2012; Reynolds et al., 2011; Tomchek et al., 2018). Furthermore, with increasing touch deprivation (e.g., social media, pandemic-related social distancing, aging populations) there is a growing need to incorporate touch-related considerations into public health structures. Psychoeducation about the benefits of affective touch, along with the development of inclusive interventions that are sensitive to sensory profiles and cultural backgrounds, can help strengthen social bonds and reduce loneliness.

6.7. Conclusion

The current dissertation provides converging evidence for the role of affective touch in social, emotional, and sensory aspects of human experience. By combining a psychometric validation, behavioural paradigms, and neurophysiological measures, this work offers a multidimensional understanding of how CT-targeted touch is perceived and processed across different contexts and

populations. The findings consistently demonstrate that CT-optimal touch, whether directly felt or observed, is rated as more pleasant, engages distinct neural oscillatory patterns, and is modulated by individual differences in tactile experiences, attitudes toward touch, and empathy. These effects were evident not only in neurotypical participants but also in individuals with ASD, who showed intact hedonic responses to CT-optimal touch, despite lower scores on empathy and touch-related traits.

Together, the results highlight that affective touch is not merely a peripheral or passive sensory modality; it is embedded in interpersonal functioning and socio-affective interpersonal communication. The influence of contextual factors such as touch speed and skin location, alongside variables like past touch experiences and empathy, underscores the importance of adopting an integrative perspective that connects sensory input with psychological meaning. Furthermore, the use of EEG revealed that CT-targeted touch modulates neural activity in ways that are consistent with enhanced attentional engagement, emotional salience, and social relevance, revealing the temporal rhythms through which the brain prioritises social connection.

Building on these empirical contributions, this dissertation advances a conceptual framework in which affective touch operates as both an embodied and predictive process that underlies social connection. From this perspective, CT-targeted stimulation is not only a source of sensory pleasure but also part of a broader neurocognitive system that integrates bottom-up tactile input with top-down emotional and cognitive expectations. Through this dynamic interaction, affective touch contributes to the continuous generation and updating of internal models of social safety and affiliation, facilitating adaptive emotional regulation and interpersonal attunement. This integrative framework bridges sensory, interoceptive, and socio-affective domains, highlighting how affective touch supports both individual well-being and the maintenance of social bonds across development.

Finally, this dissertation contributes to the growing literature that positions affective touch as a key component of human development and well-being. It also reinforces the importance of studying touch through ecologically valid and inclusive methods, particularly in populations with atypical sensory profiles. By shifting the focus from a deficit-based view to one of sensory diversity, these findings support the idea that affective touch is a powerful connection tool that not only conveys information but actively regulates and shapes the core of our social and emotional lives.

6.8. References

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APPENDIXES

A.1. Item-Total and Mean Inter-Item Correlations for Each Item of the TEAQ Subscales

Table A.1

Item-Total and Mean Inter-Item Correlations for Each Item of the TEAQ Subscales

Factor and items	Item-total correlation
FFT	
Q4	.45
Q13	.66
Q14	.70
Q16	.63
Q20	.72
Q28	.72
Q36	.70
Q45	.57
Q48	.56
Q51	.71
Q52	.63
CIT	
Q11	.57
Q17	.54
Q18	.45
Q23	.53
Q25	.63
Q27	.43
Q34	.60
Q39	.75
Q42	.77
Q43	.65
Q46	.60
ChT	
Q5	.79
Q6	.71
Q9	.72
Q15	.65
Q21	.67
Q30	.49
Q31	.81
Q33	.68
ASC	
Q2	.62
Q7	.67
Q40	.64
Q49	.44
Q50	.61
AIT	
Q8	.50

Q10	.52
Q12	.66
Q19	.44
Q22	.66
Q24	.53
Q29	.59
Q32	.66
Q38	.57
Q41	.68
Q44	.69
Q47	.65
AUT	
Q1	.38
Q3	.47
Q26	.55
Q35	.69
Q37	.69

Note. The mean inter-item is .46 for FFT, .40 for CIT, .53 for ChT, .46 for ASC, .40 for AIT, and .41 for AUT. FFT - Friends and Family Touch; CIT - Current Intimate Touch; ChT - Childhood Touch; ASC - Attitude to Self-Care; AIT - Attitude to Intimate Touch; AUT - Attitude to Unfamiliar Touch.

A.2. Pearson Correlations Between Items and Items Means and Standard Deviations

Table A.2

Items Means and Standard Deviations

Items	Mean	*SD*	N
Q1	3.08	1.24	384
Q2	3.54	1.28	384
Q3	1.83	1.07	384
Q4	3.95	1.15	384
Q5	3.82	1.17	384
Q6	3.65	1.27	384
Q7	3.05	1.31	384
Q8	4.24	0.97	384
Q9	3.82	1.28	384
Q10	4.01	1.09	384
Q11	3.55	1.31	384
Q12	4.44	0.84	384
Q13	3.24	1.36	384
Q14	3.51	1.34	384
Q15	4.03	1.01	384
Q16	3.54	1.21	384
Q17	3.88	1.18	384
Q18	4.08	1.01	384
Q19	4.42	0.80	384
Q20	3.73	1.21	384
Q21	3.61	1.39	384
Q22	4.04	0.98	384
Q23	2.46	1.40	384

Q24	4.31	0.95	384
Q25	3.13	1.38	384
Q26	1.85	1.04	384
Q27	3.07	1.20	384
Q28	3.02	1.31	384
Q29	4.47	0.77	384
Q30	4.17	1.05	384
Q31	3.89	1.15	384
Q32	4.43	0.85	384
Q33	4.29	0.98	384
Q34	3.58	1.39	384
Q35	2.38	1.17	384
Q36	3.73	1.01	384
Q37	2.24	1.13	384
Q38	4.15	0.94	384
Q39	3.49	1.42	384
Q40	3.52	1.25	384
Q41	4.59	0.68	384
Q42	3.29	1.28	384
Q43	3.94	1.11	384
Q44	4.34	0.89	384
Q45	3.12	1.25	384
Q46	3.07	1.45	384
Q47	4.18	0.91	384
Q48	2.49	1.27	384
Q49	2.95	1.32	384
Q50	3.27	1.47	384
Q51	3.86	1.11	384
Q52	2.80	1.38	384

Table A.3

Pearson Correlations Between Items

		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47	Q48	Q49	Q50	Q51	Q52
Q1	*r*	1	.153	.242	.213	.150	.232	.082	.227	.168	.169	.082	.179	.314	.376	.244	.312	.131	.184	.175	.489	.140	.259	0.001	.181	-0.041	.311	.184	.376	.343	.120	.217	.179	.126	.165	.315	.393	.314	.240	-0.011	0.075	.128	0.054	.111	.171	.352	0.072	.274	.296	0.042	0.034	.447	.197
	p		0.003	<.001	<.001	0.003	<.001	0.108	<.001	<.001	<.001	0.11	<.001	<.001	<.001	<.001	<.001	0.01	<.001	<.001	<.001	0.006	<.001	0.981	<.001	0.422	<.001	<.001	<.001	<.001	0.019	<.001	<.001	0.013	0.001	<.001	<.001	<.001	<.001	0.836	0.141	0.012	0.287	0.03	<.001	<.001	0.157	<.001	<.001	0.412	0.509	<.001	<.001
Q2	*r*		1	-0.007	.244	0.095	.140	.608	.219	0.069	.235	.211	.184	.254	.135	.217	.334	.320	.215	.138	.227	.128	.254	.213	.200	.167	0	.145	.199	.243	.209	.136	.225	.179	.188	0.067	.166	0.055	.254	.171	.502	.217	.283	.260	.201	.190	.194	.294	.192	.305	.481	.188	.255
	p			0.89	<.001	0.063	0.006	<.001	<.001	0.176	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.007	<.001	0.012	<.001	<.001	<.001	0.001	0.996	0.005	<.001	<.001	<.001	0.007	<.001	<.001	<.001	0.191	0.001	0.286	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Q3	*r*			1	0.067	0.08	.136	0.047	0.003	0.083	0.056	0.078	0.01	.156	.177	0.022	.145	0.016	0.051	-0.054	.180	-0.034	.119	0.066	0.03	0.076	.391	0.074	.197	0.007	-0.069	0.008	0.049	-0.019	.117	.405	.154	.407	0.031	-0.016	-0.031	-0.07	0.067	0.084	0.046	.218	0.014	0.027	.178	0.014	-0.065	.145	0.09
	p				0.192	0.115	0.008	0.355	0.952	0.104	0.276	0.126	0.843	0.002	<.001	0.668	0.005	0.758	0.321	0.293	<.001	0.506	0.02	0.198	0.553	0.14	<.001	0.146	<.001	0.891	0.179	0.874	0.343	0.718	0.021	<.001	0.002	<.001	0.545	0.758	0.544	0.172	0.189	0.102	0.372	<.001	0.783	0.598	<.001	0.777	0.206	0.004	0.078
Q4	*r*				1	.233	.303	.196	.225	.121	.238	.212	.192	.228	.312	.271	.626	.185	.208	.123	.362	.159	.180	0.096	.152	0.085	0.02	.201	.355	.320	.181	.251	.212	.275	.344	0.061	.365	.124	.244	.158	.143	.232	.215	.244	.162	.281	0.063	.269	.176	.131	.144	.438	.231
	p					<.001	<.001	<.001	<.001	0.018	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.016	<.001	0.002	<.001	0.06	0.003	0.098	0.699	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.233	<.001	0.015	<.001	0.002	0.005	<.001	<.001	<.001	0.001	<.001	0.217	<.001	<.001	0.01	0.005	<.001	<.001
Q5	*r*					1	.729	.108	.116	.729	.127	.123	0.065	.276	.330	.536	.319	.231	.270	.172	.268	.543	.173	.122	0.076	.172	0.083	.262	.320	.188	.381	.679	.130	.577	.365	.156	.353	.159	.130	.138	0.007	.172	.242	.218	0.075	.318	.137	.108	.143	0.096	0.074	.295	.225
	p						<.001	0.034	0.023	<.001	0.013	0.016	0.206	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.016	0.139	<.001	0.105	<.001	<.001	<.001	<.001	<.001	0.011	<.001	<.001	0.002	<.001	0.002	0.011	0.007	0.884	<.001	<.001	<.001	0.141	<.001	0.007	0.035	0.005	0.061	0.146	<.001	<.001
Q6	*r*						1	0.09	0.076	.669	0.053	.144	.103	.380	.452	.538	.388	.236	.290	.191	.431	.474	.163	.101	.130	.153	0.088	.233	.437	.241	.296	.586	.152	.500	.349	.129	.444	.160	.199	.149	0.028	.157	.235	.271	.105	.365	.146	.175	.236	0.068	0.052	.399	.334
	p							0.079	0.139	<.001	0.303	0.005	0.043	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.001	0.048	0.011	0.003	0.085	<.001	<.001	<.001	<.001	<.001	0.003	<.001	<.001	0.011	<.001	0.002	<.001	0.003	0.58	0.002	<.001	<.001	0.04	<.001	0.004	<.001	<.001	0.182	0.311	<.001	<.001
Q7	*r*							1	.241	0.077	.206	.222	.150	.261	.136	.176	.256	.264	.206	0.093	.149	.207	.208	.211	.115	.150	0.011	.144	.219	.184	.205	.164	.183	.140	.203	0.048	.141	0.029	.197	.185	.533	.242	.301	.261	.240	.176	.159	.179	.203	.435	.454	.126	.268
	p								<.001	0.131	<.001	<.001	0.003	<.001	0.007	<.001	<.001	<.001	<.001	0.069	0.003	<.001	<.001	<.001	0.024	0.003	0.823	0.005	<.001	<.001	<.001	0.001	<.001	0.006	<.001	0.346	0.006	0.576	<.001	<.001	<.001	<.001	<.001	<.001	0.002	<.001	<.001	<.001	<.001	0.014	<.001
Q8	*r*								1	0.087	.384	.329	.342	.221	.186	.198	.238	.267	.174	.187	.267	.135	.423	.177	.263	.101	-0.001	.132	.149	.400	.219	.208	.348	.162	.221	0.062	.203	0.052	.336	.215	.176	.364	.212	.260	.356	.138	.143	.352	.161	.125	.178	.234	.213
	p									0.089	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.008	<.001	<.001	<.001	0.049	0.992	0.01	0.004	<.001	<.001	<.001	<.001	0.001	<.001	0.227	<.001	0.309	<.001	<.001	<.001	<.001	<.001	<.001	0.007	0.005	<.001	0.002	0.014	<.001	<.001	<.001
Q9	*r*									1	0.034	.113	0.032	.230	.283	.461	.180	.150	.229	0.063	.223	.543	.116	0.01	0.041	.101	.139	.206	.288	.127	.277	.656	0.045	.477	.335	0.099	.360	.103	0.058	0.097	0.004	.116	.155	.110	0.037	.287	0.088	0.094	.186	0.064	0.071	.233	.221
	p										0.511	0.027	0.529	<.001	<.001	<.001	<.001	0.003	<.001	0.216	<.001	<.001	0.023	0.852	0.423	0.048	0.006	<.001	<.001	0.013	<.001	<.001	0.382	<.001	<.001	0.053	<.001	0.043	0.26	0.057	0.945	0.023	0.002	0.032	0.473	<.001	0.084	0.066	<.001	0.209	0.167	<.001	<.001
Q10	*r*										1	.520	.364	.231	.119	.181	.248	.331	.173	.194	.293	.119	.395	.330	.276	.247	0.034	.176	.139	.294	.154	.111	.354	.141	.308	0.021	0.098	0.046	.386	.318	.185	.323	.332	.307	.435	.116	.480	.493	.160	.220	.172	.167	.171
	p											<.001	<.001	<.001	0.02	<.001	<.001	<.001	<.001	<.001	<.001	0.019	<.001	<.001	<.001	<.001	0.504	<.001	0.006	<.001	0.002	0.029	<.001	0.006	<.001	0.686	0.055	0.364	<.001	<.001	<.001	<.001	<.001	<.001	0.023	<.001	<.001	0.002	<.001	<.001	0.001	<.001
Q11	*r*											1	.343	.287	.210	.159	.285	.368	.239	.140	.336	0.068	.312	.406	.286	.355	0.043	.224	.205	.243	.127	.115	.254	.198	.411	-0.041	.216	-0.046	.320	.474	0.08	.299	.462	.452	.328	.198	.468	.524	.259	.193	.128	.150	.258
	p												<.001	<.001	<.001	0.002	<.001	<.001	<.001	0.006	<.001	0.182	<.001	<.001	<.001	<.001	0.397	<.001	<.001	<.001	0.013	0.024	<.001	<.001	<.001	0.424	<.001	0.372	<.001	<.001	0.118	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.012	0.003	<.001
Q12	*r*												1	.126	.165	.148	.258	.351	.137	.379	.268	0.064	.489	.296	.665	.332	.124	.108	.104	.327	.182	0.068	.472	.142	.231	.120	.175	.112	.301	.419	.161	.614	.270	.346	.454	.157	.222	.463	0.083	0.063	0.08	.156	0.055
	p													0.013	0.001	0.004	<.001	<.001	0.007	<.001	<.001	0.211	<.001	<.001	<.001	<.001	0.015	0.034	0.041	<.001	<.001	0.186	<.001	0.005	<.001	0.019	<.001	0.028	<.001	<.001	0.002	<.001	<.001	<.001	0.002	<.001	<.001	0.106	0.214	0.118	0.002	0.279
Q13	*r*													1	.508	.307	.421	.325	.234	.143	.513	.199	.272	.163	0.065	0.076	.146	.163	.481	.307	.211	.234	.195	.309	.327	.109	.492	0.075	.294	.152	.171	.180	.243	.313	.232	.345	.209	.287	.495	.154	.162	.498	.698
	p														<.001	<.001	<.001	<.001	<.001	0.005	<.001	<.001	<.001	0.001	0.201	0.138	0.004	0.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.145	<.001	0.003	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.002	0.001	<.001	<.001
Q14	*r*														1	.407	.461	.199	.207	.195	.602	.270	.311	0.08	.137	0.046	.151	.172	.692	.439	.245	.368	.245	.327	.269	.194	.566	.164	.280	.136	0.085	.264	.215	.287	.249	.457	.127	.288	.374	.112	0.048	.592	.415
	p															<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.119	0.007	0.365	0.003	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.001	<.001	0.008	0.097	<.001	<.001	<.001	<.001	<.001	0.013	<.001	<.001	0.028	0.346	<.001	<.001
Q15	*r*															1	.447	.225	.318	.135	.367	.466	.242	0.047	.135	.109	0.079	.229	.392	.332	.411	.624	.188	.523	.326	.111	.379	.101	.193	.100	.163	.219	.192	.255	.160	.317	.151	.231	.192	.158	.147	.360	.311
	p																<.001	<.001	<.001	0.008	<.001	<.001	<.001	0.356	0.008	0.032	0.12	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.029	<.001	0.047	<.001	0.05	0.001	<.001	<.001	<.001	0.002	<.001	0.003	<.001	<.001	0.002	0.004	<.001	<.001
Q16	*r*																1	.381	.327	.225	.507	.259	.348	.194	.214	.138	.118	.287	.472	.392	.287	.332	.225	.337	.391	.143	.478	.156	.331	.224	.245	.283	.314	.386	.242	.391	.142	.351	.310	.177	.182	.544	.352
	p																	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.007	0.021	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.005	<.001	0.002	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Q17	*r*																	1	.293	.226	.335	.187	.366	.288	.306	.323	-0.007	.227	.214	.298	.165	.193	.388	.270	.399	0.017	.225	0.001	.541	.451	.213	.425	.424	.652	.413	0.088	.301	.416	.180	.215	.240	.219	.268
	p																	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.896	<.001	<.001	<.001	<.001	0.001	<.001	<.001	<.001	0.737	<.001	0.985	<.001	<.001	<.001	<.001	<.001	<.001	0.087	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Q18	*r*																		1	.179	.355	.178	.163	.212	.101	.219	0.018	.528	.223	.222	.270	.354	0.071	.201	.361	0.044	.314	0.067	.222	.301	.171	.200	.372	.336	.169	.189	.264	.265	.197	.179	.230	.243	.227
	p																			<.001	<.001	<.001	0.001	<.001	0.047	<.001	0.722	<.001	<.001	<.001	<.001	0.164	<.001	<.001	0.389	<.001	0.192	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Q19	*r*																			1	.247	.145	.311	.153	.308	0.097	.101	.282	.168	.350	.146	.150	.312	.145	.147	0.099	.199	0.073	.259	.225	.128	.464	.139	.196	.292	.187	.140	.336	0.069	.107	0.07	.157	0.085
	p																				<.001	0.005	<.001	0.003	<.001	0.057	0.049	<.001	<.001	<.001	0.004	0.003	<.001	0.005	0.004	0.052	<.001	0.156	<.001	<.001	0.012	<.001	0.006	<.001	<.001	<.001	0.006	<.001	0.175	0.036	0.173	0.002	0.096
Q20	*r*																				1	.175	.393	.182	.228	.107	.165	.274	.609	.501	.214	.266	.312	.248	.423	.189	.586	.212	.410	.267	.146	.294	.336	.406	.351	.478	.264	.425	.449	.128	0.078	.565	.466
	p																					<.001	<.001	<.001	<.001	0.036	0.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.004	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.012	0.125	<.001	<.001
Q21	*r*																					1	0.09	0.03	0.004	0.056	-0.05	.173	.252	.127	.423	.651	0.089	.539	.294	0.006	.283	-0.016	.113	0.063	.161	.113	.114	0.095	0.024	.181	0.078	.146	.152	0.093	0.097	.230	.181
	p																						0.077	0.558	0.944	0.275	0.33	<.001	<.001	0.012	<.001	<.001	0.081	<.001	<.001	0.9	<.001	0.748	0.027	0.215	0.002	0.027	0.026	0.062	0.646	<.001	0.128	0.004	0.003	0.07	0.058	<.001	<.001
Q22	*r*																						1	.260	.360	.147	.140	.196	.272	.455	.142	.115	.547	.187	.248	.144	.327	.131	.445	.262	.171	.426	.309	.395	.575	.250	.238	.469	.163	0.088	.103	.307	.223
	p																							<.001	<.001	0.004	0.006	<.001	<.001	<.001	0.005	0.025	<.001	<.001	<.001	0.005	<.001	0.01	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.001	0.084	0.043	<.001	<.001
Q23	*r*																							1	.331	.511	.109	.245	.105	0.053	0.055	0.073	.210	0.026	.230	0.05	0.046	0.01	.169	.500	0.097	.220	.425	.321	.263	.151	.424	.263	.115	.188	0.094	0.011	.102
	p																								<.001	<.001	0.033	<.001	0.04	0.3	0.283	0.156	<.001	0.611	<.001	0.327	0.373	0.85	<.001	<.001	0.057	<.001	<.001	<.001	<.001	0.003	<.001	<.001	0.024	<.001	0.067	0.835	0.046
Q24	*r*																								1	.467	.143	0.092	0.096	.270	.141	0.073	.462	.125	.242	0.059	.118	0.055	.210	.419	.128	.497	.298	.263	.365	.150	.239	.346	0.002	0.028	0.049	.136	-0.009
	p																									<.001	0.005	0.072	0.059	<.001	0.005	0.151	<.001	0.015	<.001	0.249	0.021	0.281	<.001	<.001	0.012	<.001	<.001	<.001	<.001	0.003	<.001	<.001	0.964	0.579	0.339	0.008	0.862
Q25	*r*																									1	0.03	.256	0.059	-0.026	0.051	.104	.155	0.071	.419	-0.028	-0.021	-0.057	0.093	.666	.109	.215	.625	.400	.203	0.071	.414	.206	0.07	.103	.113	-0.002	0.056
	p																										0.555	<.001	0.249	0.608	0.32	0.042	0.002	0.163	<.001	0.588	0.684	0.263	0.068	<.001	0.033	<.001	<.001	<.001	<.001	0.166	<.001	<.001	0.171	0.043	0.027	0.974	0.271
Q26	*r*																										1	.124	.215	0.083	-0.044	0.061	0.082	0.025	0.069	.478	.173	.463	-0.009	-0.034	-0.055	-0.002	0.024	-0.007	0.049	.315	0.092	0.048	.256	-0.041	-.150	.171	.108
	p																											0.015	<.001	0.103	0.391	0.233	0.11	0.629	0.176	<.001	<.001	<.001	0.853	0.509	0.284	0.974	0.634	0.885	0.339	<.001	0.072	0.348	<.001	0.419	0.003	<.001	0.035

Table A.3 *(continued)*

Q27	*r*	1	.245	.194	.220	.303	.137	.145	.343	.178	.248	.189	.165	.284	0.091	.155	.375	.289	.130	.280	.265	.215	.193	.160	.151	.184	.160
	p		<.001	<.001	<.001	<.001	0.007	0.004	<.001	<.001	<.001	<.001	0.001	<.001	0.074	0.002	<.001	<.001	0.011	<.001	<.001	<.001	<.001	0.002	0.003	<.001	0.002
Q28	*r*		1	.402	.195	.327	.214	.291	.325	.197	.562	.205	.256	.117	.155	.203	.244	.251	.202	.487	.204	.212	.422	.125	0.091	.586	.469
	p			<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.022	0.002	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.014	0.076	<.001	<.001
Q29	*r*			1	.246	.214	.481	.308	.231	.145	.435	.144	.493	.124	.163	.472	.184	.334	.441	.320	.145	.435	.193	.139	.110	.478	.293
	p				<.001	<.001	<.001	<.001	<.001	0.004	<.001	0.005	<.001	0.015	0.001	<.001	<.001	<.001	<.001	<.001	0.004	<.001	<.001	0.006	0.031	<.001	<.001
Q30	*r*				1	.485	.154	.483	.240	0.043	.281	-0.002	.139	.124	.221	.172	.151	.179	.153	.244	0.072	.224	0.092	.144	.201	.278	.162
	p					<.001	0.003	<.001	<.001	0.404	<.001	0.972	0.006	0.015	<.001	<.001	0.003	<.001	0.003	<.001	0.16	<.001	0.071	0.005	<.001	<.001	0.001
Q31	*r*					1	0.095	.624	.361	0.089	.378	0.058	.161	.103	.146	.136	.185	.186	0.068	.306	0.078	.146	.173	.118	.148	.312	.230
	p						0.064	<.001	<.001	0.08	<.001	0.258	0.002	0.043	0.004	0.008	<.001	<.001	0.182	<.001	0.129	0.004	<.001	0.021	0.004	<.001	<.001
Q32	*r*						1	.230	.235	.110	.239	.137	.435	.264	0.084	.494	.253	.362	.587	.131	.254	.426	0.09	0.041	-0.009	.258	.133
	p							<.001	<.001	0.031	<.001	0.007	<.001	<.001	0.102	<.001	<.001	<.001	<.001	0.01	<.001	<.001	0.079	0.421	0.854	<.001	0.009
Q33	*r*							1	.310	0.006	.353	-0.007	.208	.124	.128	.191	.135	.223	.135	.216	0.053	.211	0.089	0.077	.112	.345	.304
	p								<.001	0.905	<.001	0.896	<.001	0.015	0.012	<.001	0.008	<.001	0.008	<.001	0.303	<.001	0.082	0.132	0.028	<.001	<.001
Q34	*r*								1	0.064	.330	0.083	.248	.490	.149	.238	.614	.442	.220	.201	.404	.325	.231	0.093	0.09	.243	.277
	p									0.213	<.001	0.106	<.001	<.001	0.003	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.069	0.079	<.001	<.001
Q35	*r*									1	.152	.804	-0.011	-0.058	-0.018	0.074	0.076	0.025	0.065	.326	-0.004	0.086	.211	-0.029	-0.056	.250	.119
	p										0.003	<.001	0.835	0.259	0.731	0.149	0.139	0.631	0.206	<.001	0.942	0.093	<.001	0.572	0.276	<.001	0.02
Q36	*r*										1	.185	.243	0.092	.112	.269	.192	.267	.221	.453	.114	.298	.432	0.069	.128	.576	.470
	p											<.001	<.001	0.071	0.028	<.001	<.001	<.001	<.001	<.001	0.026	<.001	<.001	0.18	0.012	<.001	<.001
Q37	*r*											1	-0.014	-0.062	-0.024	0.064	0.047	0.011	0.062	.289	0.022	0.073	.196	-0.006	-0.031	.245	.120
	p												0.785	0.226	0.633	0.211	0.363	0.83	0.225	<.001	0.661	0.154	<.001	0.899	0.545	<.001	0.019
Q38	*r*												1	.307	.183	.404	.241	.602	.510	.200	.248	.483	.265	.186	.133	.311	.319
	p													<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.009	<.001	<.001
Q39	*r*													1	.108	.344	.675	.563	.406	.151	.530	.375	.144	.150	.134	0.045	.107
	p														0.034	<.001	<.001	<.001	<.001	0.003	<.001	<.001	0.005	0.003	0.009	0.382	0.036
Q40	*r*														1	.231	.200	.202	.129	0.092	.105	.170	.110	.322	.575	.124	.196
	p															<.001	<.001	<.001	0.011	0.07	0.039	<.001	0.03	<.001	<.001	0.015	<.001
Q41	*r*															1	.270	.401	.517	.139	.201	.465	0.09	.161	.177	.263	.152
	p																<.001	<.001	<.001	0.006	<.001	<.001	0.078	0.002	<.001	<.001	0.003
Q42	*r*																1	.537	.378	.178	.549	.323	.204	.234	.216	.143	.227
	p																	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.005	<.001
Q43	*r*																	1	.504	.196	.404	.484	.258	.222	.154	.208	.306
	p																		<.001	<.001	<.001	<.001	<.001	<.001	0.002	<.001	<.001
Q44	*r*																		1	.215	.357	.549	.145	.155	0.068	.217	.178
	p																			<.001	<.001	<.001	0.005	0.002	0.184	<.001	<.001
Q45	*r*																			1	.173	.280	.435	.118	.113	.462	.356
	p																				<.001	<.001	<.001	0.02	0.027	<.001	<.001
Q46	*r*																				1	.365	.269	.152	0.055	0.071	.207
	p																					<.001	<.001	0.003	0.278	0.166	<.001
Q47	*r*																					1	.235	.164	.142	.312	.211
	p																						<.001	0.001	0.005	<.001	<.001
Q48	*r*																						1	.155	.119	.344	.559
	p																							0.002	0.02	<.001	<.001
Q49	*r*																							1	.351	.117	.176
	p																								<.001	0.022	<.001
Q50	*r*																								1	0.093	.225
	p																									0.067	<.001
Q51	*r*																									1	.444
	p																										<.001
Q52	*r*																										1
	p																										

A.3. Multi-Group Confirmatory Factor Analysis

Table A.4

Standardized Loadings for the Six-Factor Model for Combined, Female, and Male Data

	Factor loadings		
Factor and items	Combined data	Female	Male
FFT			
Q4	.59	.60	.54
Q13	.68	.66	.73
Q14	.76	.75	.82
Q16	.67	.69	.59
Q20	.78	.77	.80
Q28	.77	.76	.81
Q36	.74	.74	.75
Q45	.61	.61	.64
Q48	.57	.55	.61
Q51	.70	.71	.66
Q52	.64	.62	.68
CIT			
Q11	.61	.60	.57
Q17	.61	.61	.55
Q18	.45	.37	.67
Q23	.56	.64	.27
Q25	.68	.75	.52
Q27	.44	.37	.62
Q34	.66	.62	.74
Q39	.81	.83	.78
Q42	.82	.84	.69
Q43	.71	.69	.69
Q46	.64	.64	.62
ChT			
Q5	.84	.86	.82
Q6	.78	.77	.84
Q9	.78	.76	.89
Q15	.69	.74	.53
Q21	.69	.69	.72
Q30	.51	.52	.41
Q31	.84	.85	.74
Q33	.71	.72	.64
ASC			
Q2	.74	.69	.78
Q7	.77	.75	.80
Q40	.71	.66	.58
Q49	.50	.45	.41
Q50	.66	.57	.50
AIT			
Q8	.53	.50	.60
Q10	.56	.62	.40

Q12	.69	.70	.72
Q19	.47	.50	.41
Q22	.71	.70	.70
Q24	.58	.62	.61
Q29	.63	.58	.72
Q32	.70	.70	.77
Q38	.62	.63	.57
Q41	.71	.69	.81
Q44	.75	.73	.80
Q47	.70	.69	.71
AUT			
Q1	.39	.34	.59
Q3	.48	.42	.58
Q26	.55	.54	.52
Q35	.89	.91	.80
Q37	.89	.89	.84

Note. FFT - Friends and Family Touch; CIT - Current Intimate Touch; ChT - Childhood Touch; ASC - Attitude to Self-Care; AIT - Attitude to Intimate Touch; AUT - Attitude to Unfamiliar Touch.

Table A.5

Standardized Loadings for the Parcelled Six-Factor Model for Combined, Female, and Male Data

	Factor loadings		
Factor and items	Combined data	Female	Male
FFT			
Q28, 48, 52	.81	.80	.83
Q13, 14, 20, 51	.93	.92	.96
Q4, 16, 36, 45	.80	.79	.79
CIT			
Q17, 18, 34, 39	.89	.89	.98
Q11, 23, 25, 27	.79	.82	.64
Q42, 43, 46	.88	.87	.80
ChT			
Q9, 21	.81	.81	.81
Q5, 15, 30	.86	.86	.86
Q6, 31, 33	.97	.97	.92
ASC			
Q50	.68	.58	.54
Q2, 7	.78	.75	.82
Q40, 49	.79	.73	.70
AIT			
Q19, 24, 32, 44	.83	.85	.86
Q8, 12, 41	.81	.81	.83
Q10, 22, 29, 38, 47	.86	.85	.84
AUT			
Q37	.74	.73	.72
Q1, 35	.93	.92	.94
Q3, 26	.59	.55	.65

Note. A multi-group confirmatory factor analysis between the two groups (female and male) was made to examine factor invariance. Tables 1 and 2 provide the factors, items, and standardized loadings for the combined, female, and male data, for the six-factor model and for the parcelled six-factor model, respectively. These results show that the items are comparable separate and combined, functioning in a similar way across groups, and that both can produce equivalent results. FFT - Friends and Family Touch; CIT - Current Intimate Touch; ChT - Childhood Touch; ASC - Attitude to Self-Care; AIT - Attitude to Intimate Touch; AUT - Attitude to Unfamiliar Touch.

A.4. European Portuguese Version of the Touch Experiences and Attitudes Questionnaire

Table A.6

European Portuguese version of the Touch Experiences and Attitudes Questionnaire

	Discordo completamente	Discordo um pouco	Não concordo nem discordo	Concordo um pouco	Concordo completamente
1. Eu não gosto quando as pessoas são muito afetuosas fisicamente em relação a mim.					
2. Eu gosto de usar loções corporais.					
3. Eu tenho de conhecer alguém relativamente bem para desfrutar do seu abraço.					
4. Eu considero que é natural cumprimentar os meus amigos e familiares com um beijo na bochecha.					
5. Houve muito afeto físico durante a minha infância.					
6. Em criança, eu costumava abraçar os membros da minha família frequentemente.					
7. Eu gosto de usar essências de banho quando tomo banho.					
8. Eu considero que acariciar o cabelo de uma pessoa que gosto é muito agradável.					
9. Os meus pais não foram muito afetuosos fisicamente em relação a mim durante a minha infância.					
10. Eu gosto de adormecer nos braços de alguém de quem sou próximo(a).					

11. Eu costumo aconchegar-me no sofá com alguém.					
12. Eu gosto da intimidade física dos preliminares sexuais.					
13. Eu gosto de dar o braço aos meus amigos e familiares enquanto ando.					
14. Eu normalmente abraço os meus familiares e amigos quando estou a despedir-me.					
15. Em criança, receber um abraço dos meus pais quando eu estava triste fazia com que eu me sentisse muito mais feliz.					
16. É bom quando amigos e membros da família me cumprimentam com um beijo.					
17. Eu costumo dar as mãos a alguém que conheço intimamente.					
18. Quando eu estou triste, geralmente há alguém que me consegue confortar.					
19. Beijar é uma boa forma de expressar atração física.					
20. Eu abraço regularmente pessoas de quem sou próximo(a).					
21. Em criança, os meus pais aconchegavam-me na cama todas as noites e davam-me um abraço e um beijo de boa noite.					
22. Eu gosto quando a minha pele é acariciada.					

23. Eu costumo tomar um duche ou um banho com alguém.					
24. Eu gosto de fazer sexo.					
25. Eu faço sexo frequentemente.					
26. Eu não gosto de ter proximidade física com pessoas que não conheço bem.					
27. Eu consigo sempre encontrar alguém para me confortar fisicamente quando não me sinto bem					
28. Eu cumprimento sempre os meus amigos e familiares dando-lhes um abraço.					
29. Eu aprecio ser abraçado(a) por alguém de quem gosto.					
30. A minha mãe dava-me banho regularmente quando eu era criança.					
31. Em criança, os meus pais confortavam-me sempre quando eu estava triste.					
32. Eu gosto da sensação da minha pele a tocar na de outra pessoa se eu a conhecer intimamente.					
33. Em criança, os meus pais costumavam dar-me a mão quando eu caminhava com eles.					
34. Na maioria dos dias eu recebo um abraço ou um beijo.					
35. Se alguém que eu não conheço muito bem coloca a sua mão de forma amigável no meu					

braço, isso faz-me sentir desconfortável.					
36. Eu costumo ter contacto físico com os meus amigos e familiares quando estou com eles.					
37. Faz-me sentir desconfortável se alguém que eu não conheço muito bem me toca de uma maneira amigável.					
38. Eu aprecio dar a mão a alguém de quem gosto.					
39. Eu costumo partilhar um beijo romântico com frequência.					
40. Eu gosto de exfoliar a minha pele.					
41. Beijar é uma parte agradável de expressar sentimentos românticos.					
42. A minha pele é acariciada frequentemente.					
43. Eu costumo dar a mão a alguém de quem gosto.					
44. Eu gosto de acariciar a pele de alguém que eu conheço intimamente.					
45. Eu consigo ser abraçado(a) por relativamente muitas pessoas.					
46. Eu costumo adormecer enquanto abraço alguém de quem eu sou próximo(a).					
47. Abraçar alguém no sofá é muito bom.					
48. Eu costumo colocar o braço sobre um amigo próximo enquanto caminhamos juntos.					

49. Eu gosto de tomar banho com muita espuma.					
50. Eu gosto de usar máscaras faciais na minha pele.					
51. Eu gosto quando os meus amigos e familiares me cumprimentam dando-me um abraço.					
52. Eu costumo andar de braços dados com os meus amigos e familiares quando passeamos.					

Note. The item numbers below identify which subscale each item corresponds to (R identifies items that are reverse scored): Friends and family touch (FFT) (11 items): 4, 13, 14, 16, 20, 28, 36, 45, 48, 51, 52; Current intimate touch (CIT) (11 items): 11, 17, 18, 23, 25, 27, 34, 39, 42, 43, 46; Childhood touch (ChT) (8 items): 5, 6, 9R, 15, 21, 30, 31, 33; Attitude to self-care (ASC) (5 items): 2, 7, 40, 49, 50; Attitude to intimate touch (AIT) (12 items): 8, 10, 12, 19, 22, 24, 29, 32, 38, 41, 44, 47; Attitude to unfamiliar touch (AUT) (5 items): 1R, 3R, 26R, 35R, 37R.

B.1. Control Exploratory Study

B.1.1. Objective

To address the potential influence of the differences in the Speed of the stimuli across conditions -irrespective of other psychosocial cues- we conducted an additional exploratory study using dots moving at different Speeds as stimuli instead of videos of social touch.

B.1.2. Methods

B.1.2.1. Participants

This sample consisted of 10 participants aged between 19 and 37 years (M = 26.00; SD = 4.78), including 6 females, 3 males, and 1 non-binary individual. All of them reported normal or corrected vision. Exclusion criteria were the presence of head injury or other current neurological or psychiatric conditions. Participants were recruited through convenience sampling.

B.1.2.2. Procedure and Experimental Task

In this control experiment, we presented participants with the same experimental conditions of our main study (Static, Slow, and Fast) but using simple dot stimuli instead of touch videos, ensuring that visual motion was isolated from any touch-related cues, while EEG data was being recorded. Participants viewed videos depicting point-light displays simulating the movement of the social touch. Five distinct videos (repeated 6 times) of the dots were presented for each one of three motion conditions: Static, Slow, and Fast, making a total of 30 videos per condition. In the Static condition, the dot exhibited Brownian motion to mimic the subtle physiological tremor observed in the Hands of the actors in the main experiment's naturalistic touch videos. The Slow and Fast conditions displayed the dot animating Back and forth in different orientations at Speeds comparable to the movements in the naturalistic touch videos. The stimulus presentation order was randomized for each participant. See Figure B.1 for a visual representation of the task.

Figure B.1

Example of the Stimuli Used in the Exploratory Task



Note. The five Static videos featured a white dot presented in the center of the screen. Brownian motion was added to these dots to give them movement characteristics similar to those of the social touch videos. In the Slow and Fast motion videos, the dots moved in a Back-and-forth motion, each video in a different direction and with different movement distances, so as to resemble the movements performed by the actors in the social touch videos.

B.1.2.3. EEG Recording and Analysis

We used the same parameters reported in the main study. In contrast to the main study, we assessed the Late Positive Potential (LPP) solely at electrode Pz. This decision was based on the observation that the LPP exhibited lower amplitudes at the remaining electrodes analyzed previously (CPz and Cz). Furthermore, midfrontal theta time-frequency data was measured at electrode FCz, since theta activity was more clearly modulated at this Location for dots videos. The parameters for all other analyses remained unchanged.

B.1.3. Results

B.1.3.1. Power Spectral Density (PSD)

The repeated measures ANOVA for alpha (9-12 Hz) showed a significant main effect of Speed [$F(2,18) = 4.88$, $p = .02$, $\eta p^2 = 0.35$], with paired comparisons showing higher alpha PSD for the Static condition than for the Fast condition ($t = 3.12$, $p = .02$, Cohen's $d = 0.17$). Repeated measures ANOVA did not show a significant effect of Speed for theta (3-6Hz) [$F(2,18) = 2.01$, $p = .15$, $\eta p^2 = 0.19$] nor for beta PSD (16-22 Hz), [$F(2,18) = 1.68$, $p = .21$, $\eta p^2 = 0.16$]. See Figure B.2.

B.1.3.2. Late Positive Potential (LPP)

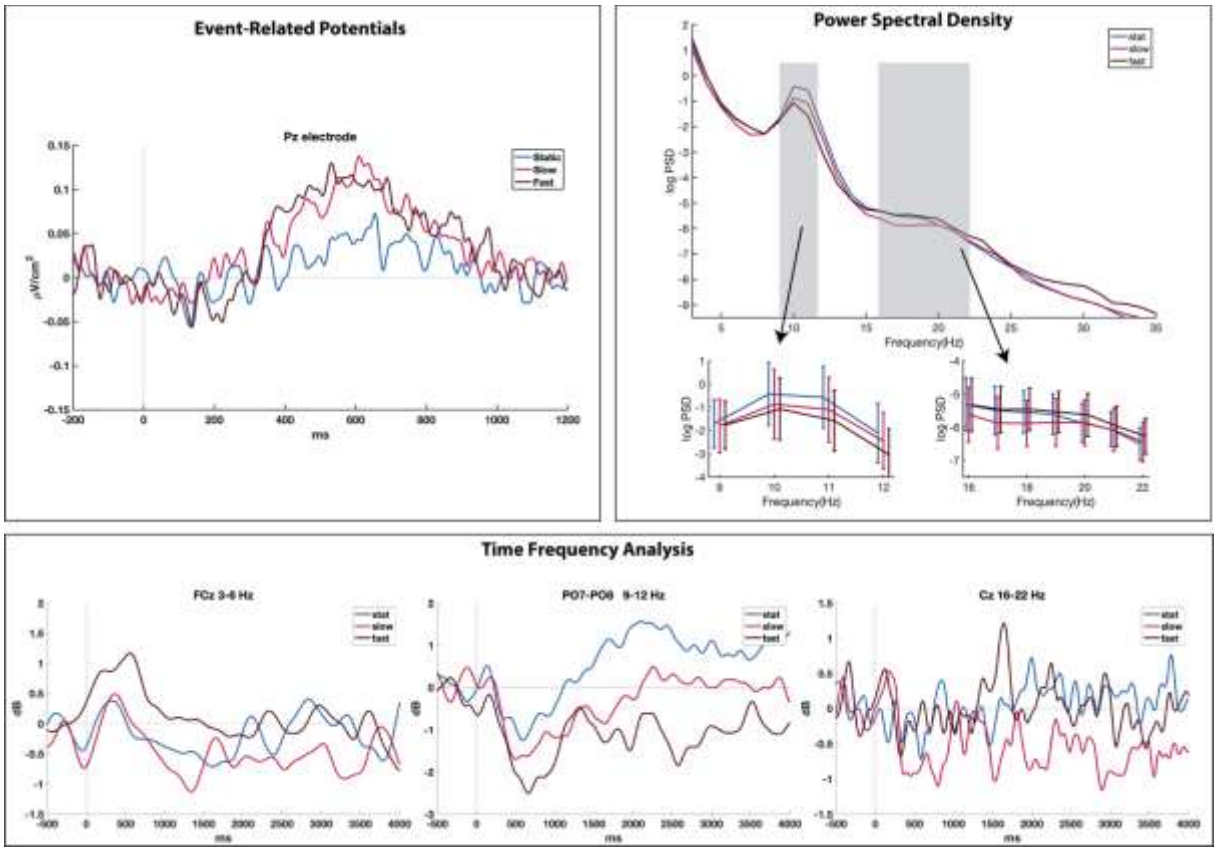
For the LPP over the Pz electrode, the repeated measures ANOVA of the mean amplitude in the window from 350 to 600 ms showed a significant main effect of Speed [$F(2,18) = 6.90$, $p = .006$, $\eta p^2 = 0.43$], with paired comparisons showing higher amplitudes for the Slow and Fast conditions than for the Static condition (Static vs Slow: $t = -2.62$, $p = .04$, Cohen's $d = 0.88$; Static vs Fast: $t = -3.59$, $p = .006$, Cohen's $d = 1.20$). See Figure B.2.

B.1.3.3. Time-Frequency

The repeated measures ANOVA on the posterior alpha activity (9-12 Hz; 300-3700 ms; PO7 and PO8 electrodes) revealed a main effect of Speed [$F(2,18) = 3.29$, $p = .06$, $\eta p^2 = 0.27$], and post-hoc paired comparisons showed a significantly higher alpha power for the Static condition than for the Fast condition ($t = 2.56$, $p = .06$, Cohen's $d = 0.97$). The ANOVA on the mid-frontal theta oscillatory activity (3-6 Hz; 300-700 ms; FCz electrode) [$F(2,18) = 0.66$, $p = .53$, $\eta p^2 = 0.07$] and on the beta band over the vertex (16-22 Hz; 300-3700 ms; Cz electrode) [$F(2,18) = 1.78$, $p = .20$, $\eta p^2 = 0.17$] did not show a significant effect of Speed. Here we used the FCz electrode for theta analysis, and not the Fz as in the main study, since it presented greater amplitude. See Figure B.2.

Figure B.2

Brain Activity Evoked in Each of the Experimental Conditions



B.1.4. Conclusion

The results of this experiment indicate that while posterior alpha power differences between Static and dynamic conditions persisted, likely influenced by visual motion processing, beta suppression—our key finding in the main study—was absent in this control condition. This suggests that the beta desynchronisation observed in the main study was not merely driven by low-level visual differences related to Speed but instead reflects the affective and somatosensory relevance of vicarious touch. These findings support the interpretation that CT-optimal touch engages neural mechanisms beyond motion processing, reinforcing its biological and social significance.

Figure B.3

Difference in the Pleasantness/Willingness Scores for Each Condition (Speed and Skin Location) for the Question "How Pleasant do You Think That Action was for the Person Being Touched?" (Other) and for the Question "How Much Would You Like to be Touched Like That?" (Self) - Individual Trends

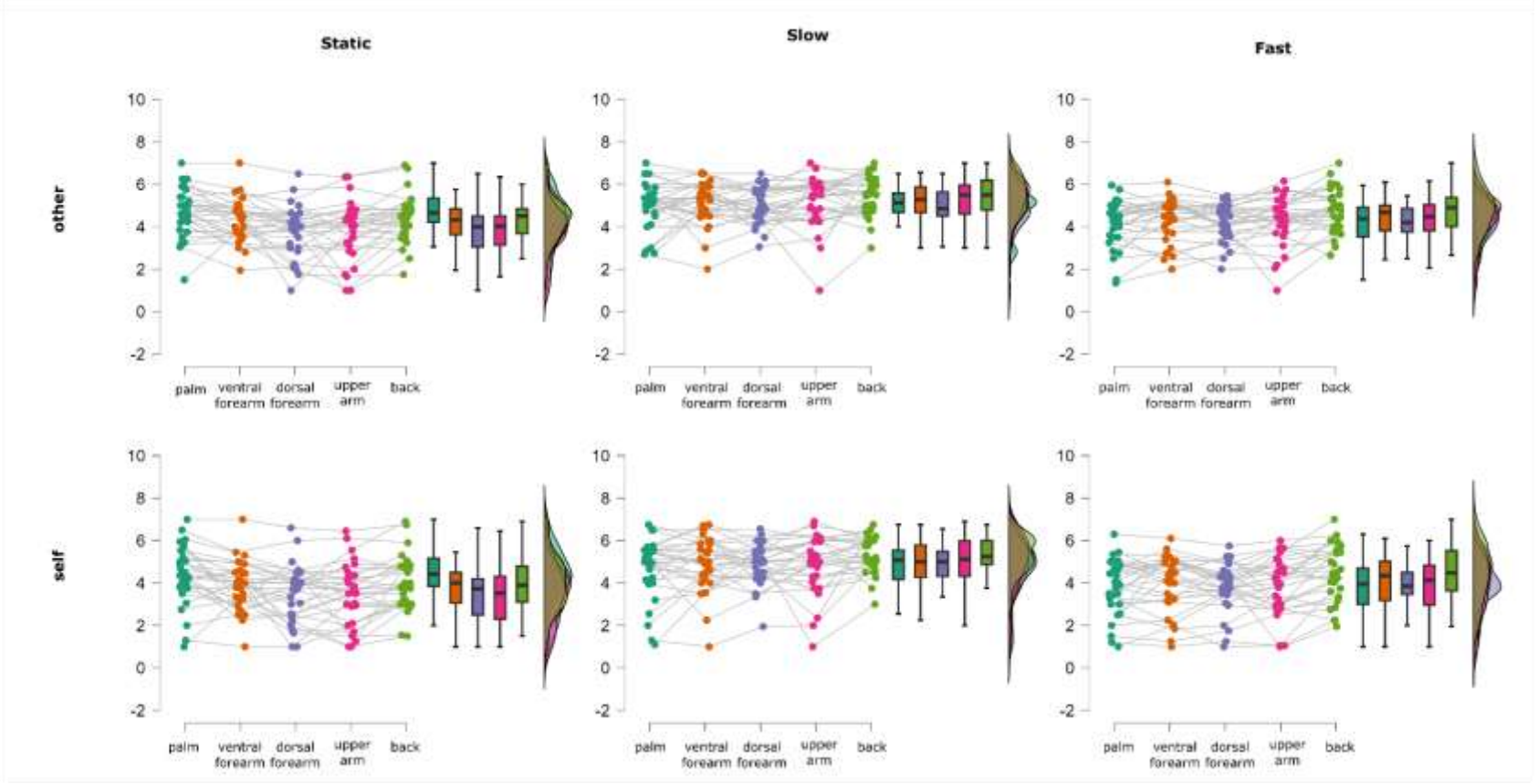


Table B.1

Correlation Coefficients Between TEAQ Scores and Participants' Response to Questions

	FFT	CIT	ChT	ASC	AIT	AUT	Total
Other							
Static	0.16	0.24	-0.06	-0.37*	0.21	0.39*	0.17
Slow	0.11	0.26	-0.04	-0.001	0.29	0.20	0.22
Fast	0.32	0.35	0.22	-0.18	0.24	062***	0.41*
Back	0.24	0.12	0.09	-0.21	-0.09	0.33	0.15
Upper Arm	0.21	0.10	-0.05	-0.39*	0.09	0.45*	0.13
Ventral Forearm	0.16	0.42*	0.12	-0.11	0.50**	0.52**	0.40*
Dorsal Forearm	0.25	0.35	-0.007	-0.23	0.29	0.46*	0.30
Palm	0.09	0.41*	0.05	0.04	0.40*	0.31	0.32
Back x Static	0.16	0.09	-0.02	-0.29	0.04	0.28	0.09
Back x Slow	0.21	-0.05	0.006	-0.03	-024	0.23	0.04
Back x Fast	0.22	0.25	0.24	-0.17	-0.05	0.32	0.24
Upper Arm x Static	0.23	0.20	0.005	-0.42*	0.17	0.39*	0.19
Upper Arm x Slow	0.06	-0.03	-0.14	-0.24	0.05	0.27	-0.006
Upper Arm x Fast	0.26	0.06	0.008	-0.35	0.000	0.51**	0.15
Ventral Forearm x Static	0.05	0.27	-0.12	-0.18	0.31	0.38*	0.18
Ventral Forearm x Slow	0.12	0.38*	0.15	0.01	0.51**	0.31	0.37*
Ventral Forearm x Fast	0.23	0.39*	0.26	-0.11	0.42*	0.60***	0.45*
Dorsal Forearm x Static	0.20	0.28	-0.12	-0.29	0.20	0.38*	0.19
Dorsal Forearm x Slow	0.08	0.16	-0.11	-0.10	0.26	0.18	0.12
Dorsal Forearm x Fast	0.30	0.40*	0.25	-0.12	0.25	0.54*	0.43*
Palm x Static	-0.03	0.14	-0.02	-0.29	0.13	0.12	0.03
Palm x Slow	-0.05	0.44*	-0.05	0.35	0.41*	0.02	0.26
Palm x Fast	0.28	0.37*	0.18	0.04	0.38*	0.56**	0.45*
Self							
Static	0.23	0.31	-0.004	-0.31	0.36	0.48**	0.29
Slow	0.26	0.40*	0.07	0.03	0.53***	0.40*	0.43*
Fast	0.39*	0.40*	0.24	-0.12	0.39*	0.65***	0.51**
Back	0.35	0.23	0.23	-0.21	0.06	0.47**	0.32
Upper Arm	0.28	0.20	0.01	-0.40*	0.26	0.51**	0.25
Ventral Forearm	0.30	0.51**	0.17	-0.02	0.65***	0.56**	0.54**
Dorsal Forearm	0.29	0.39*	0.04	-0.16	0.45*	0.49**	0.39*
Palm	0.19	0.43*	0.06	0.14	0.52**	0.38*	0.42*
Back x Static	0.27	0.17	0.13	-0.31	0.17	0.39*	0.24
Back x Slow	0.26	0.10	0.12	0.05	-0.08	0.35	0.21
Back x Fast	0.34	0.27	0.31	-0.20	0.009	0.44*	0.34
Upper Arm x Static	0.26	0.29	0.02	-0.40*	0.29	0.46**	0.27
Upper Arm x Slow	0.14	0.10	-0.07	-0.30	0.22	0.34	0.12
Upper Arm x Fast	0.35	0.14	0.07	-0.37*	0.17	0.56**	0.26
Ventral Forearm x Static	0.11	0.35	-0.03	-0.07	0.45*	0.43*	0.30
Ventral Forearm x Slow	0.32	0.47**	0.19	0.09	0.66***	0.41*	0.54**
Ventral Forearm x Fast	0.34	0.47**	0.24	-0.06	0.56**	0.60***	0.54**
Dorsal Forearm x Static	0.22	0.32	-0.13	-0.20	0.29	0.43*	0.25
Dorsal Forearm x Slow	0.10	0.22	-0.02	-0.11	0.41*	0.17	0.20
Dorsal Forearm x Fast	0.37*	0.40*	0.27	-0.07	0.43*	0.56**	0.51**

Palm x Static	0.06	0.15	-0.004	-0.23	0.26	0.23	0.12
Palm x Slow	0.15	0.50**	0.03	0.36	0.57**	0.20	0.43*
Palm x Fast	0.26	0.41*	0.13	0.22	0.45*	0.54**	0.48**

Note. FFT – Friends and Family Touch; CIT – Current Intimate Touch; ChT – Childhood Touch; ASC – Attitude to Self-Care; AIT – Attitude to Intimate Touch; AUT – Attitude to Unfamiliar Touch; * $p < .05$; ** $p < .01$; *** $p < .001$. Uncorrected p-value.

Table C.1

Post Hoc Comparisons for the Body Location × Speed Interaction from the Repeated Measures ANOVA on NRS Self Ratings

		Mean Difference	SE	*t*	Cohen's *d*	p_{holm}
Ventral Forearm, Static	Dorsal Forearm, Static	0.094	0.165	0.569	0.076	1.000
	Upper Arm, Static	0.311	0.165	1.881	0.250	1.000
	Hand, Static	-0.875	0.165	-5.297	-0.703	1.382×10^{-5}
	Back, Static	-0.377	0.165	-2.281	-0.303	0.912
	Ventral Forearm, Slow	-0.852	0.173	-4.932	-0.684	9.077×10^{-5}
	Dorsal Forearm, Slow	-0.623	0.183	-3.407	-0.500	0.047
	Upper Arm, Slow	-1.052	0.183	-5.755	-0.844	1.198×10^{-6}
	Hand, Slow	-0.427	0.183	-2.335	-0.342	0.811
	Back, Slow	-1.025	0.183	-5.611	-0.823	2.659×10^{-6}
	Ventral Forearm, Fast	-0.418	0.173	-2.421	-0.336	0.695
	Dorsal Forearm, Fast	-0.438	0.183	-2.397	-0.351	0.722
	Upper Arm, Fast	-0.210	0.183	-1.147	-0.168	1.000
	Hand, Fast	0.036	0.183	0.198	0.029	1.000
	Back, Fast	-0.914	0.183	-5.003	-0.734	6.154×10^{-5}
Dorsal Forearm, Static	Upper Arm, Static	0.217	0.165	1.312	0.174	1.000
	Hand, Static	-0.969	0.165	-5.866	-0.778	6.292×10^{-7}
	Back, Static	-0.471	0.165	-2.850	-0.378	0.255
	Ventral Forearm, Slow	-0.946	0.183	-5.178	-0.759	2.586×10^{-5}
	Dorsal Forearm, Slow	-0.717	0.173	-4.149	-0.575	0.003
	Upper Arm, Slow	-1.146	0.183	-6.270	-0.919	6.170×10^{-8}
	Hand, Slow	-0.521	0.183	-2.850	-0.418	0.255
	Back, Slow	-1.119	0.183	-6.126	-0.898	1.459×10^{-7}
	Ventral Forearm, Fast	-0.512	0.183	-2.804	-0.411	0.285
	Dorsal Forearm, Fast	-0.532	0.173	-3.080	-0.427	0.136
	Upper Arm, Fast	-0.304	0.183	-1.662	-0.244	1.000
	Hand, Fast	-0.058	0.183	-0.317	-0.046	1.000
	Back, Fast	-1.008	0.183	-5.518	-0.809	4.381×10^{-6}
Upper Arm, Static	Hand, Static	-1.186	0.165	-7.178	-0.952	1.642×10^{-10}
	Back, Static	-0.688	0.165	-4.162	-0.552	0.003
	Ventral Forearm, Slow	-1.163	0.183	-6.365	-0.933	3.493×10^{-8}
	Dorsal Forearm, Slow	-0.933	0.183	-5.109	-0.749	3.641×10^{-5}
	Upper Arm, Slow	-1.362	0.173	-7.887	-1.093	1.538×10^{-12}
	Hand, Slow	-0.738	0.183	-4.037	-0.592	0.005
	Back, Slow	-1.336	0.183	-7.313	-1.072	7.180×10^{-11}
	Ventral Forearm, Fast	-0.729	0.183	-3.990	-0.585	0.006
	Dorsal Forearm, Fast	-0.749	0.183	-4.099	-0.601	0.004
	Upper Arm, Fast	-0.521	0.173	-3.013	-0.418	0.164
	Hand, Fast	-0.275	0.183	-1.503	-0.220	1.000
	Back, Fast	-1.225	0.183	-6.705	-0.983	4.118×10^{-9}
Hand, Static	Back, Static	0.498	0.165	3.016	0.400	0.164
	Ventral Forearm, Slow	0.023	0.183	0.128	0.019	1.000

	Dorsal Forearm, Slow	0.253	0.183	1.384	0.203	1.000
	Upper Arm, Slow	-0.176	0.183	-0.964	-0.141	1.000
	Hand, Slow	0.449	0.173	2.597	0.360	0.486
	Back, Slow	-0.150	0.183	-0.820	-0.120	1.000
	Ventral Forearm, Fast	0.457	0.183	2.502	0.367	0.578
	Dorsal Forearm, Fast	0.437	0.183	2.394	0.351	0.722
	Upper Arm, Fast	0.666	0.183	3.644	0.534	0.021
	Hand, Fast	0.912	0.173	5.277	0.732	1.650×10^{-5}
	Back, Fast	-0.039	0.183	-0.212	-0.031	1.000
Back, Static	Ventral Forearm, Slow	-0.475	0.183	-2.600	-0.381	0.486
	Dorsal Forearm, Slow	-0.246	0.183	-1.344	-0.197	1.000
	Upper Arm, Slow	-0.675	0.183	-3.692	-0.541	0.018
	Hand, Slow	-0.050	0.183	-0.272	-0.040	1.000
	Back, Slow	-0.648	0.173	-3.752	-0.520	0.014
	Ventral Forearm, Fast	-0.041	0.183	-0.225	-0.033	1.000
	Dorsal Forearm, Fast	-0.061	0.183	-0.334	-0.049	1.000
	Upper Arm, Fast	0.167	0.183	0.916	0.134	1.000
	Hand, Fast	0.413	0.183	2.262	0.332	0.926
	Back, Fast	-0.537	0.173	-3.110	-0.431	0.126
Ventral Forearm, Slow	Dorsal Forearm, Slow	0.229	0.165	1.388	0.184	1.000
	Upper Arm, Slow	-0.200	0.165	-1.208	-0.160	1.000
	Hand, Slow	0.425	0.165	2.573	0.341	0.492
	Back, Slow	-0.173	0.165	-1.048	-0.139	1.000
	Ventral Forearm, Fast	0.434	0.173	2.511	0.348	0.578
	Dorsal Forearm, Fast	0.414	0.183	2.266	0.332	0.926
	Upper Arm, Fast	0.642	0.183	3.516	0.516	0.033
	Hand, Fast	0.888	0.183	4.861	0.713	1.201×10^{-4}
	Back, Fast	-0.062	0.183	-0.340	-0.050	1.000
Dorsal Forearm, Slow	Upper Arm, Slow	-0.429	0.165	-2.596	-0.344	0.486
	Hand, Slow	0.196	0.165	1.185	0.157	1.000
	Back, Slow	-0.403	0.165	-2.436	-0.323	0.678
	Ventral Forearm, Fast	0.204	0.183	1.119	0.164	1.000
	Dorsal Forearm, Fast	0.185	0.173	1.069	0.148	1.000
	Upper Arm, Fast	0.413	0.183	2.260	0.331	0.926
	Hand, Fast	0.659	0.183	3.606	0.529	0.024
	Back, Fast	-0.292	0.183	-1.596	-0.234	1.000
Upper Arm, Slow	Hand, Slow	0.625	0.165	3.781	0.501	0.013
	Back, Slow	0.026	0.165	0.160	0.021	1.000
	Ventral Forearm, Fast	0.633	0.183	3.467	0.508	0.038
	Dorsal Forearm, Fast	0.614	0.183	3.358	0.492	0.055
	Upper Arm, Fast	0.842	0.173	4.874	0.676	1.191×10^{-4}
	Hand, Fast	1.088	0.183	5.954	0.873	3.993×10^{-7}
	Back, Fast	0.137	0.183	0.752	0.110	1.000
Hand, Slow	Back, Slow	-0.598	0.165	-3.621	-0.480	0.022
	Ventral Forearm, Fast	0.009	0.183	0.047	0.007	1.000
	Dorsal Forearm, Fast	-0.011	0.183	-0.061	-0.009	1.000
	Upper Arm, Fast	0.217	0.183	1.188	0.174	1.000
	Hand, Fast	0.463	0.173	2.680	0.372	0.401

	Back, Fast	-0.487	0.183	-2.668	-0.391	0.406
Back, Slow	Ventral Forearm, Fast	0.607	0.183	3.322	0.487	0.062
	Dorsal Forearm, Fast	0.587	0.183	3.214	0.471	0.089
	Upper Arm, Fast	0.816	0.183	4.464	0.655	7.740×10^{-4}
	Hand, Fast	1.061	0.183	5.809	0.852	8.994×10^{-7}
	Back, Fast	0.111	0.173	0.643	0.089	1.000
Ventral	Dorsal Forearm, Fast	-0.020	0.165	-0.120	-0.016	1.000
Forearm,	Upper Arm, Fast	0.209	0.165	1.262	0.167	1.000
Fast	Hand, Fast	0.454	0.165	2.749	0.365	0.329
	Back, Fast	-0.496	0.165	-3.001	-0.398	0.166
Dorsal	Upper Arm, Fast	0.228	0.165	1.382	0.183	1.000
Forearm,	Hand, Fast	0.474	0.165	2.869	0.381	0.245
Fast	Back, Fast	-0.476	0.165	-2.881	-0.382	0.240
Upper Arm,	Hand, Fast	0.246	0.165	1.487	0.197	1.000
Fast	Back, Fast	-0.705	0.165	-4.263	-0.565	0.002
Hand, Fast	Back, Fast	-0.950	0.165	-5.751	-0.763	1.195×10^{-6}

Note. Results are averaged over the levels of: Group and Sex. SE- standard error of the coefficient; *t* - Student's *t*-test.

Table C.2

Post Hoc Comparisons for the Body Location × Speed × Group Interaction from the Repeated Measures ANOVA on NRS Self Ratings

		Mean Difference	SE	*t*	Cohen's *d*	p_{holm}
ASD, Ventral Forearm, Static	Control, Ventral Forearm, Static	0.115	0.301	0.383	0.092	1.000
	ASD, Dorsal Forearm, Static	0.031	0.239	0.131	0.025	1.000
	Control, Dorsal Forearm, Static	0.272	0.301	0.904	0.218	1.000
	ASD, Upper Arm, Static	0.047	0.239	0.199	0.038	1.000
	Control, Upper Arm, Static	0.690	0.301	2.292	0.553	1.000
	ASD, Hand, Static	-0.963	0.239	-4.033	-0.773	0.024
	Control, Hand, Static	-0.672	0.301	-2.234	-0.540	1.000
	ASD, Back, Static	-0.225	0.239	-0.940	-0.180	1.000
	Control, Back, Static	-0.414	0.301	-1.377	-0.332	1.000
	ASD, Ventral Forearm, Slow	-0.771	0.250	-3.087	-0.618	0.723
	Control, Ventral Forearm, Slow	-0.818	0.301	-2.719	-0.657	1.000
	ASD, Dorsal Forearm, Slow	-0.651	0.264	-2.467	-0.523	1.000
	Control, Dorsal Forearm, Slow	-0.479	0.301	-1.590	-0.384	1.000
	ASD, Upper Arm, Slow	-0.876	0.264	-3.316	-0.703	0.347

	Control, Upper Arm, Slow	-1.112	0.301	-3.696	-0.893	0.094
	ASD, Hand, Slow	-0.636	0.264	-2.408	-0.510	1.000
	Control, Hand, Slow	-0.102	0.301	-0.340	-0.082	1.000
	ASD, Back, Slow	-0.838	0.264	-3.174	-0.673	0.555
	Control, Back, Slow	-1.097	0.301	-3.646	-0.880	0.112
	ASD, Ventral Forearm, Fast	-0.411	0.250	-1.645	-0.330	1.000
	Control, Ventral Forearm, Fast	-0.310	0.301	-1.032	-0.249	1.000
	ASD, Dorsal Forearm, Fast	-0.461	0.264	-1.745	-0.370	1.000
	Control, Dorsal Forearm, Fast	-0.300	0.301	-0.997	-0.241	1.000
	ASD, Upper Arm, Fast	0.137	0.264	0.518	0.110	1.000
	Control, Upper Arm, Fast	-0.441	0.301	-1.465	-0.354	1.000
	ASD, Hand, Fast	-0.135	0.264	-0.510	-0.108	1.000
	Control, Hand, Fast	0.322	0.301	1.071	0.259	1.000
	ASD, Back, Fast	-0.938	0.264	-3.552	-0.753	0.152
	Control, Back, Fast	-0.775	0.301	-2.576	-0.622	1.000
Control, Ventral Forearm, Static	ASD, Dorsal Forearm, Static	-0.084	0.301	-0.278	-0.067	1.000
	Control, Dorsal Forearm, Static	0.157	0.228	0.686	0.126	1.000
	ASD, Upper Arm, Static	-0.068	0.301	-0.225	-0.054	1.000
	Control, Upper Arm, Static	0.574	0.228	2.514	0.461	1.000
	ASD, Hand, Static	-1.078	0.301	-3.584	-0.865	0.141
	Control, Hand, Static	-0.787	0.228	-3.447	-0.632	0.220
	ASD, Back, Static	-0.340	0.301	-1.129	-0.273	1.000
	Control, Back, Static	-0.529	0.228	-2.317	-0.425	1.000
	ASD, Ventral Forearm, Slow	-0.886	0.301	-2.944	-0.711	1.000
	Control, Ventral Forearm, Slow	-0.933	0.239	-3.908	-0.749	0.041
	ASD, Dorsal Forearm, Slow	-0.767	0.301	-2.548	-0.615	1.000
	Control, Dorsal Forearm, Slow	-0.594	0.253	-2.350	-0.476	1.000
	ASD, Upper Arm, Slow	-0.991	0.301	-3.293	-0.795	0.386
	Control, Upper Arm, Slow	-1.227	0.253	-4.859	-0.985	6.103×10^{-4}
	ASD, Hand, Slow	-0.751	0.301	-2.496	-0.603	1.000

	Control, Hand, Slow	-0.218	0.253	-0.861	-0.175	1.000
	ASD, Back, Slow	-0.953	0.301	-3.168	-0.765	0.575
	Control, Back, Slow	-1.212	0.253	-4.799	-0.973	8.085×10^{-4}
	ASD, Ventral Forearm, Fast	-0.526	0.301	-1.748	-0.422	1.000
	Control, Ventral Forearm, Fast	-0.426	0.239	-1.782	-0.342	1.000
	ASD, Dorsal Forearm, Fast	-0.576	0.301	-1.914	-0.462	1.000
	Control, Dorsal Forearm, Fast	-0.415	0.253	-1.643	-0.333	1.000
	ASD, Upper Arm, Fast	0.022	0.301	0.072	0.017	1.000
	Control, Upper Arm, Fast	-0.556	0.253	-2.201	-0.446	1.000
	ASD, Hand, Fast	-0.250	0.301	-0.830	-0.200	1.000
	Control, Hand, Fast	0.207	0.253	0.820	0.166	1.000
	ASD, Back, Fast	-1.053	0.301	-3.500	-0.845	0.191
	Control, Back, Fast	-0.890	0.253	-3.525	-0.715	0.168
ASD, Dorsal Forearm, Static	Control, Dorsal Forearm, Static	0.241	0.301	0.800	0.193	1.000
	ASD, Upper Arm, Static	0.016	0.239	0.067	0.013	1.000
	Control, Upper Arm, Static	0.658	0.301	2.187	0.528	1.000
	ASD, Hand, Static	-0.995	0.239	-4.164	-0.798	0.014
	Control, Hand, Static	-0.704	0.301	-2.339	-0.565	1.000
	ASD, Back, Static	-0.256	0.239	-1.071	-0.205	1.000
	Control, Back, Static	-0.446	0.301	-1.481	-0.358	1.000
	ASD, Ventral Forearm, Slow	-0.802	0.264	-3.037	-0.644	0.840
	Control, Ventral Forearm, Slow	-0.849	0.301	-2.823	-0.682	1.000
	ASD, Dorsal Forearm, Slow	-0.683	0.250	-2.735	-0.548	1.000
	Control, Dorsal Forearm, Slow	-0.510	0.301	-1.695	-0.409	1.000
	ASD, Upper Arm, Slow	-0.907	0.264	-3.435	-0.728	0.230
	Control, Upper Arm, Slow	-1.144	0.301	-3.800	-0.918	0.064
	ASD, Hand, Slow	-0.667	0.264	-2.527	-0.535	1.000
	Control, Hand, Slow	-0.134	0.301	-0.445	-0.107	1.000
	ASD, Back, Slow	-0.869	0.264	-3.293	-0.698	0.375
	Control, Back, Slow	-1.128	0.301	-3.750	-0.906	0.077
	ASD, Ventral Forearm, Fast	-0.442	0.264	-1.674	-0.355	1.000

	Control, Ventral Forearm, Fast	-0.342	0.301	-1.136	-0.274	1.000
	ASD, Dorsal Forearm, Fast	-0.492	0.250	-1.971	-0.395	1.000
	Control, Dorsal Forearm, Fast	-0.331	0.301	-1.101	-0.266	1.000
	ASD, Upper Arm, Fast	0.105	0.264	0.399	0.085	1.000
	Control, Upper Arm, Fast	-0.472	0.301	-1.569	-0.379	1.000
	ASD, Hand, Fast	-0.166	0.264	-0.629	-0.133	1.000
	Control, Hand, Fast	0.291	0.301	0.967	0.233	1.000
	ASD, Back, Fast	-0.969	0.264	-3.671	-0.778	0.098
	Control, Back, Fast	-0.807	0.301	-2.680	-0.647	1.000
Control, Dorsal Forearm, Static	ASD, Upper Arm, Static	-0.225	0.301	-0.746	-0.180	1.000
	Control, Upper Arm, Static	0.418	0.228	1.828	0.335	1.000
	ASD, Hand, Static	-1.235	0.301	-4.105	-0.991	0.019
	Control, Hand, Static	-0.944	0.228	-4.133	-0.758	0.016
	ASD, Back, Static	-0.496	0.301	-1.650	-0.398	1.000
	Control, Back, Static	-0.686	0.228	-3.004	-0.551	0.924
	ASD, Ventral Forearm, Slow	-1.043	0.301	-3.465	-0.837	0.216
	Control, Ventral Forearm, Slow	-1.090	0.253	-4.315	-0.875	0.007
	ASD, Dorsal Forearm, Slow	-0.923	0.301	-3.069	-0.741	0.778
	Control, Dorsal Forearm, Slow	-0.750	0.239	-3.143	-0.602	0.612
	ASD, Upper Arm, Slow	-1.148	0.301	-3.814	-0.921	0.060
	Control, Upper Arm, Slow	-1.384	0.253	-5.480	-1.111	2.513×10^{-5}
	ASD, Hand, Slow	-0.908	0.301	-3.017	-0.729	0.910
	Control, Hand, Slow	-0.374	0.253	-1.482	-0.300	1.000
	ASD, Back, Slow	-1.110	0.301	-3.689	-0.891	0.096
	Control, Back, Slow	-1.369	0.253	-5.420	-1.099	3.455×10^{-5}
	ASD, Ventral Forearm, Fast	-0.683	0.301	-2.269	-0.548	1.000
	Control, Ventral Forearm, Fast	-0.582	0.253	-2.306	-0.467	1.000
	ASD, Dorsal Forearm, Fast	-0.733	0.301	-2.435	-0.588	1.000
	Control, Dorsal Forearm, Fast	-0.572	0.239	-2.395	-0.459	1.000

	ASD, Upper Arm, Fast	-0.135	0.301	-0.449	-0.109	1.000
	Control, Upper Arm, Fast	-0.713	0.253	-2.822	-0.572	1.000
	ASD, Hand, Fast	-0.407	0.301	-1.351	-0.326	1.000
	Control, Hand, Fast	0.050	0.253	0.199	0.040	1.000
	ASD, Back, Fast	-1.210	0.301	-4.021	-0.971	0.027
	Control, Back, Fast	-1.047	0.253	-4.145	-0.840	0.015
ASD, Upper Arm, Static	Control, Upper Arm, Static	0.642	0.301	2.134	0.515	1.000
	ASD, Hand, Static	-1.011	0.239	-4.232	-0.811	0.011
	Control, Hand, Static	-0.720	0.301	-2.392	-0.578	1.000
	ASD, Back, Static	-0.272	0.239	-1.139	-0.218	1.000
	Control, Back, Static	-0.462	0.301	-1.535	-0.371	1.000
	ASD, Ventral Forearm, Slow	-0.818	0.264	-3.098	-0.657	0.695
	Control, Ventral Forearm, Slow	-0.866	0.301	-2.877	-0.695	1.000
	ASD, Dorsal Forearm, Slow	-0.699	0.264	-2.647	-0.561	1.000
	Control, Dorsal Forearm, Slow	-0.526	0.301	-1.748	-0.422	1.000
	ASD, Upper Arm, Slow	-0.923	0.250	-3.698	-0.741	0.091
	Control, Upper Arm, Slow	-1.160	0.301	-3.854	-0.931	0.052
	ASD, Hand, Slow	-0.683	0.264	-2.588	-0.548	1.000
	Control, Hand, Slow	-0.150	0.301	-0.498	-0.120	1.000
	ASD, Back, Slow	-0.886	0.264	-3.354	-0.711	0.306
	Control, Back, Slow	-1.145	0.301	-3.804	-0.919	0.063
	ASD, Ventral Forearm, Fast	-0.458	0.264	-1.735	-0.368	1.000
	Control, Ventral Forearm, Fast	-0.358	0.301	-1.189	-0.287	1.000
	ASD, Dorsal Forearm, Fast	-0.508	0.264	-1.925	-0.408	1.000
	Control, Dorsal Forearm, Fast	-0.347	0.301	-1.154	-0.279	1.000
	ASD, Upper Arm, Fast	0.089	0.250	0.358	0.072	1.000
	Control, Upper Arm, Fast	-0.488	0.301	-1.623	-0.392	1.000
	ASD, Hand, Fast	-0.182	0.264	-0.690	-0.146	1.000
	Control, Hand, Fast	0.275	0.301	0.913	0.221	1.000
	ASD, Back, Fast	-0.985	0.264	-3.732	-0.791	0.078
	Control, Back, Fast	-0.823	0.301	-2.734	-0.660	1.000

Control, Upper Arm, Static	ASD, Hand, Static	-1.653	0.301	-5.493	-1.326	2.877×10^{-5}
	Control, Hand, Static	-1.362	0.228	-5.961	-1.093	1.618×10^{-6}
	ASD, Back, Static	-0.914	0.301	-3.038	-0.734	0.857
	Control, Back, Static	-1.104	0.228	-4.831	-0.886	6.827×10^{-4}
	ASD, Ventral Forearm, Slow	-1.460	0.301	-4.853	-1.172	7.134×10^{-4}
	Control, Ventral Forearm, Slow	-1.508	0.253	-5.968	-1.210	1.618×10^{-6}
	ASD, Dorsal Forearm, Slow	-1.341	0.301	-4.457	-1.076	0.004
	Control, Dorsal Forearm, Slow	-1.168	0.253	-4.624	-0.937	0.002
	ASD, Upper Arm, Slow	-1.565	0.301	-5.202	-1.256	1.290×10^{-4}
	Control, Upper Arm, Slow	-1.802	0.239	-7.544	-1.446	7.361×10^{-11}
	ASD, Hand, Slow	-1.325	0.301	-4.405	-1.064	0.005
	Control, Hand, Slow	-0.792	0.253	-3.135	-0.636	0.620
	ASD, Back, Slow	-1.528	0.301	-5.077	-1.226	2.410×10^{-4}
	Control, Back, Slow	-1.787	0.253	-7.073	-1.434	1.544×10^{-9}
	ASD, Ventral Forearm, Fast	-1.100	0.301	-3.657	-0.883	0.108
	Control, Ventral Forearm, Fast	-1.000	0.253	-3.959	-0.803	0.033
	ASD, Dorsal Forearm, Fast	-1.150	0.301	-3.823	-0.923	0.059
	Control, Dorsal Forearm, Fast	-0.989	0.253	-3.917	-0.794	0.038
	ASD, Upper Arm, Fast	-0.553	0.301	-1.837	-0.444	1.000
	Control, Upper Arm, Fast	-1.130	0.239	-4.733	-0.907	0.001
	ASD, Hand, Fast	-0.824	0.301	-2.739	-0.661	1.000
	Control, Hand, Fast	-0.367	0.253	-1.454	-0.295	1.000
	ASD, Back, Fast	-1.627	0.301	-5.409	-1.306	4.461×10^{-5}
	Control, Back, Fast	-1.465	0.253	-5.799	-1.175	4.292×10^{-6}
ASD, Hand, Static	Control, Hand, Static	0.291	0.301	0.967	0.233	1.000
	ASD, Back, Static	0.739	0.239	3.093	0.593	0.703
	Control, Back, Static	0.549	0.301	1.824	0.441	1.000
	ASD, Ventral Forearm, Slow	0.193	0.264	0.729	0.155	1.000
	Control, Ventral Forearm, Slow	0.145	0.301	0.483	0.117	1.000
	ASD, Dorsal Forearm, Slow	0.312	0.264	1.181	0.250	1.000

		Control, Dorsal Forearm, Slow	0.485	0.301	1.611	0.389	1.000
		ASD, Upper Arm, Slow	0.088	0.264	0.331	0.070	1.000
		Control, Upper Arm, Slow	-0.149	0.301	-0.495	-0.120	1.000
		ASD, Hand, Slow	0.327	0.250	1.311	0.263	1.000
		Control, Hand, Slow	0.861	0.301	2.861	0.691	1.000
		ASD, Back, Slow	0.125	0.264	0.474	0.100	1.000
		Control, Back, Slow	-0.134	0.301	-0.445	-0.107	1.000
		ASD, Ventral Forearm, Fast	0.553	0.264	2.093	0.443	1.000
		Control, Ventral Forearm, Fast	0.653	0.301	2.170	0.524	1.000
		ASD, Dorsal Forearm, Fast	0.502	0.264	1.903	0.403	1.000
		Control, Dorsal Forearm, Fast	0.663	0.301	2.205	0.532	1.000
		ASD, Upper Arm, Fast	1.100	0.264	4.166	0.883	0.014
		Control, Upper Arm, Fast	0.523	0.301	1.736	0.419	1.000
		ASD, Hand, Fast	0.829	0.250	3.319	0.665	0.347
		Control, Hand, Fast	1.286	0.301	4.272	1.032	0.010
		ASD, Back, Fast	0.025	0.264	0.096	0.020	1.000
		Control, Back, Fast	0.188	0.301	0.625	0.151	1.000
Control, Hand, Static		ASD, Back, Static	0.448	0.301	1.488	0.359	1.000
		Control, Back, Static	0.258	0.228	1.129	0.207	1.000
		ASD, Ventral Forearm, Slow	-0.098	0.301	-0.327	-0.079	1.000
		Control, Ventral Forearm, Slow	-0.146	0.253	-0.577	-0.117	1.000
		ASD, Dorsal Forearm, Slow	0.021	0.301	0.069	0.017	1.000
		Control, Dorsal Forearm, Slow	0.194	0.253	0.767	0.156	1.000
		ASD, Upper Arm, Slow	-0.203	0.301	-0.676	-0.163	1.000
		Control, Upper Arm, Slow	-0.440	0.253	-1.741	-0.353	1.000
		ASD, Hand, Slow	0.036	0.301	0.121	0.029	1.000
		Control, Hand, Slow	0.570	0.239	2.387	0.457	1.000
		ASD, Back, Slow	-0.166	0.301	-0.551	-0.133	1.000
		Control, Back, Slow	-0.425	0.253	-1.681	-0.341	1.000
		ASD, Ventral Forearm, Fast	0.262	0.301	0.870	0.210	1.000

	Control, Ventral Forearm, Fast	0.362	0.253	1.433	0.290	1.000
	ASD, Dorsal Forearm, Fast	0.212	0.301	0.703	0.170	1.000
	Control, Dorsal Forearm, Fast	0.372	0.253	1.475	0.299	1.000
	ASD, Upper Arm, Fast	0.809	0.301	2.689	0.649	1.000
	Control, Upper Arm, Fast	0.232	0.253	0.917	0.186	1.000
	ASD, Hand, Fast	0.538	0.301	1.787	0.432	1.000
	Control, Hand, Fast	0.995	0.239	4.165	0.798	0.014
	ASD, Back, Fast	-0.266	0.301	-0.883	-0.213	1.000
	Control, Back, Fast	-0.103	0.253	-0.407	-0.083	1.000
ASD, Back, Static	Control, Back, Static	-0.190	0.301	-0.631	-0.152	1.000
	ASD, Ventral Forearm, Slow	-0.546	0.264	-2.068	-0.438	1.000
	Control, Ventral Forearm, Slow	-0.594	0.301	-1.973	-0.476	1.000
	ASD, Dorsal Forearm, Slow	-0.427	0.264	-1.617	-0.343	1.000
	Control, Dorsal Forearm, Slow	-0.254	0.301	-0.844	-0.204	1.000
	ASD, Upper Arm, Slow	-0.651	0.264	-2.466	-0.523	1.000
	Control, Upper Arm, Slow	-0.888	0.301	-2.950	-0.712	1.000
	ASD, Hand, Slow	-0.411	0.264	-1.558	-0.330	1.000
	Control, Hand, Slow	0.122	0.301	0.406	0.098	1.000
	ASD, Back, Slow	-0.614	0.250	-2.458	-0.492	1.000
	Control, Back, Slow	-0.873	0.301	-2.900	-0.700	1.000
	ASD, Ventral Forearm, Fast	-0.186	0.264	-0.705	-0.149	1.000
	Control, Ventral Forearm, Fast	-0.086	0.301	-0.286	-0.069	1.000
	ASD, Dorsal Forearm, Fast	-0.236	0.264	-0.895	-0.190	1.000
	Control, Dorsal Forearm, Fast	-0.075	0.301	-0.250	-0.060	1.000
	ASD, Upper Arm, Fast	0.361	0.264	1.368	0.290	1.000
	Control, Upper Arm, Fast	-0.216	0.301	-0.719	-0.174	1.000
	ASD, Hand, Fast	0.090	0.264	0.340	0.072	1.000
	Control, Hand, Fast	0.547	0.301	1.817	0.439	1.000
	ASD, Back, Fast	-0.713	0.250	-2.858	-0.573	1.000
	Control, Back, Fast	-0.551	0.301	-1.830	-0.442	1.000

Control, Back, Static	ASD, Ventral Forearm, Slow	-0.356	0.301	-1.184	-0.286	1.000
	Control, Ventral Forearm, Slow	-0.404	0.253	-1.598	-0.324	1.000
	ASD, Dorsal Forearm, Slow	-0.237	0.301	-0.788	-0.190	1.000
	Control, Dorsal Forearm, Slow	-0.064	0.253	-0.254	-0.052	1.000
	ASD, Upper Arm, Slow	-0.461	0.301	-1.534	-0.370	1.000
	Control, Upper Arm, Slow	-0.698	0.253	-2.763	-0.560	1.000
	ASD, Hand, Slow	-0.222	0.301	-0.736	-0.178	1.000
	Control, Hand, Slow	0.312	0.253	1.235	0.250	1.000
	ASD, Back, Slow	-0.424	0.301	-1.408	-0.340	1.000
	Control, Back, Slow	-0.683	0.239	-2.859	-0.548	1.000
	ASD, Ventral Forearm, Fast	0.004	0.301	0.012	0.003	1.000
	Control, Ventral Forearm, Fast	0.104	0.253	0.411	0.083	1.000
	ASD, Dorsal Forearm, Fast	-0.047	0.301	-0.155	-0.037	1.000
	Control, Dorsal Forearm, Fast	0.114	0.253	0.453	0.092	1.000
	ASD, Upper Arm, Fast	0.551	0.301	1.831	0.442	1.000
	Control, Upper Arm, Fast	-0.026	0.253	-0.105	-0.021	1.000
	ASD, Hand, Fast	0.280	0.301	0.929	0.224	1.000
	Control, Hand, Fast	0.737	0.253	2.916	0.591	1.000
	ASD, Back, Fast	-0.524	0.301	-1.740	-0.420	1.000
	Control, Back, Fast	-0.361	0.239	-1.511	-0.290	1.000
ASD, Ventral Forearm, Slow	Control, Ventral Forearm, Slow	-0.047	0.301	-0.158	-0.038	1.000
	ASD, Dorsal Forearm, Slow	0.119	0.239	0.499	0.096	1.000
	Control, Dorsal Forearm, Slow	0.292	0.301	0.971	0.234	1.000
	ASD, Upper Arm, Slow	-0.105	0.239	-0.440	-0.084	1.000
	Control, Upper Arm, Slow	-0.341	0.301	-1.135	-0.274	1.000
	ASD, Hand, Slow	0.135	0.239	0.564	0.108	1.000
	Control, Hand, Slow	0.668	0.301	2.221	0.536	1.000
	ASD, Back, Slow	-0.067	0.239	-0.282	-0.054	1.000
	Control, Back, Slow	-0.326	0.301	-1.085	-0.262	1.000
	ASD, Ventral Forearm, Fast	0.360	0.250	1.442	0.289	1.000

	Control, Ventral Forearm, Fast	0.460	0.301	1.530	0.369	1.000
	ASD, Dorsal Forearm, Fast	0.310	0.264	1.173	0.249	1.000
	Control, Dorsal Forearm, Fast	0.471	0.301	1.565	0.378	1.000
	ASD, Upper Arm, Fast	0.907	0.264	3.436	0.728	0.229
	Control, Upper Arm, Fast	0.330	0.301	1.096	0.265	1.000
	ASD, Hand, Fast	0.636	0.264	2.409	0.510	1.000
	Control, Hand, Fast	1.093	0.301	3.632	0.877	0.118
	ASD, Back, Fast	-0.167	0.264	-0.633	-0.134	1.000
	Control, Back, Fast	-0.005	0.301	-0.015	-0.004	1.000
Control, Ventral Forearm, Slow	ASD, Dorsal Forearm, Slow	0.167	0.301	0.554	0.134	1.000
	Control, Dorsal Forearm, Slow	0.340	0.228	1.486	0.273	1.000
	ASD, Upper Arm, Slow	-0.058	0.301	-0.192	-0.046	1.000
	Control, Upper Arm, Slow	-0.294	0.228	-1.287	-0.236	1.000
	ASD, Hand, Slow	0.182	0.301	0.605	0.146	1.000
	Control, Hand, Slow	0.716	0.228	3.132	0.574	0.622
	ASD, Back, Slow	-0.020	0.301	-0.067	-0.016	1.000
	Control, Back, Slow	-0.279	0.228	-1.221	-0.224	1.000
	ASD, Ventral Forearm, Fast	0.407	0.301	1.354	0.327	1.000
	Control, Ventral Forearm, Fast	0.508	0.239	2.126	0.407	1.000
	ASD, Dorsal Forearm, Fast	0.357	0.301	1.187	0.287	1.000
	Control, Dorsal Forearm, Fast	0.518	0.253	2.051	0.416	1.000
	ASD, Upper Arm, Fast	0.955	0.301	3.173	0.766	0.567
	Control, Upper Arm, Fast	0.377	0.253	1.494	0.303	1.000
	ASD, Hand, Fast	0.683	0.301	2.271	0.548	1.000
	Control, Hand, Fast	1.140	0.253	4.514	0.915	0.003
	ASD, Back, Fast	-0.120	0.301	-0.398	-0.096	1.000
	Control, Back, Fast	0.043	0.253	0.170	0.034	1.000
ASD, Dorsal Forearm, Slow	Control, Dorsal Forearm, Slow	0.173	0.301	0.575	0.139	1.000
	ASD, Upper Arm, Slow	-0.224	0.239	-0.939	-0.180	1.000
	Control, Upper Arm, Slow	-0.461	0.301	-1.531	-0.370	1.000

	ASD, Hand, Slow	0.016	0.239	0.065	0.012	1.000
	Control, Hand, Slow	0.549	0.301	1.825	0.441	1.000
	ASD, Back, Slow	-0.187	0.239	-0.782	-0.150	1.000
	Control, Back, Slow	-0.446	0.301	-1.481	-0.358	1.000
	ASD, Ventral Forearm, Fast	0.241	0.264	0.912	0.193	1.000
	Control, Ventral Forearm, Fast	0.341	0.301	1.133	0.274	1.000
	ASD, Dorsal Forearm, Fast	0.191	0.250	0.764	0.153	1.000
	Control, Dorsal Forearm, Fast	0.352	0.301	1.168	0.282	1.000
	ASD, Upper Arm, Fast	0.788	0.264	2.985	0.633	0.982
	Control, Upper Arm, Fast	0.211	0.301	0.700	0.169	1.000
	ASD, Hand, Fast	0.517	0.264	1.957	0.415	1.000
	Control, Hand, Fast	0.974	0.301	3.236	0.781	0.467
	ASD, Back, Fast	-0.286	0.264	-1.085	-0.230	1.000
	Control, Back, Fast	-0.124	0.301	-0.411	-0.099	1.000
Control, Dorsal Forearm, Slow	ASD, Upper Arm, Slow	-0.397	0.301	-1.320	-0.319	1.000
	Control, Upper Arm, Slow	-0.634	0.228	-2.773	-0.509	1.000
	ASD, Hand, Slow	-0.157	0.301	-0.523	-0.126	1.000
	Control, Hand, Slow	0.376	0.228	1.646	0.302	1.000
	ASD, Back, Slow	-0.360	0.301	-1.195	-0.289	1.000
	Control, Back, Slow	-0.619	0.228	-2.707	-0.496	1.000
	ASD, Ventral Forearm, Fast	0.068	0.301	0.225	0.054	1.000
	Control, Ventral Forearm, Fast	0.168	0.253	0.665	0.135	1.000
	ASD, Dorsal Forearm, Fast	0.018	0.301	0.059	0.014	1.000
	Control, Dorsal Forearm, Fast	0.179	0.239	0.748	0.143	1.000
	ASD, Upper Arm, Fast	0.615	0.301	2.045	0.494	1.000
	Control, Upper Arm, Fast	0.038	0.253	0.149	0.030	1.000
	ASD, Hand, Fast	0.344	0.301	1.143	0.276	1.000
	Control, Hand, Fast	0.801	0.253	3.170	0.643	0.559
	ASD, Back, Fast	-0.459	0.301	-1.527	-0.369	1.000
	Control, Back, Fast	-0.297	0.253	-1.174	-0.238	1.000
ASD, Upper Arm, Slow	Control, Upper Arm, Slow	-0.236	0.301	-0.786	-0.190	1.000
	ASD, Hand, Slow	0.240	0.239	1.004	0.192	1.000
	Control, Hand, Slow	0.773	0.301	2.570	0.621	1.000

	ASD, Back, Slow	0.038	0.239	0.158	0.030	1.000
	Control, Back, Slow	-0.221	0.301	-0.736	-0.178	1.000
	ASD, Ventral Forearm, Fast	0.465	0.264	1.761	0.373	1.000
	Control, Ventral Forearm, Fast	0.565	0.301	1.879	0.454	1.000
	ASD, Dorsal Forearm, Fast	0.415	0.264	1.571	0.333	1.000
	Control, Dorsal Forearm, Fast	0.576	0.301	1.914	0.462	1.000
	ASD, Upper Arm, Fast	1.012	0.250	4.056	0.813	0.022
	Control, Upper Arm, Fast	0.435	0.301	1.446	0.349	1.000
	ASD, Hand, Fast	0.741	0.264	2.807	0.595	1.000
	Control, Hand, Fast	1.198	0.301	3.981	0.961	0.032
	ASD, Back, Fast	-0.062	0.264	-0.235	-0.050	1.000
	Control, Back, Fast	0.101	0.301	0.334	0.081	1.000
Control, Upper Arm, Slow	ASD, Hand, Slow	0.476	0.301	1.583	0.382	1.000
	Control, Hand, Slow	1.010	0.228	4.420	0.810	0.005
	ASD, Back, Slow	0.274	0.301	0.911	0.220	1.000
	Control, Back, Slow	0.015	0.228	0.066	0.012	1.000
	ASD, Ventral Forearm, Fast	0.701	0.301	2.331	0.563	1.000
	Control, Ventral Forearm, Fast	0.802	0.253	3.174	0.643	0.555
	ASD, Dorsal Forearm, Fast	0.651	0.301	2.165	0.523	1.000
	Control, Dorsal Forearm, Fast	0.812	0.253	3.216	0.652	0.485
	ASD, Upper Arm, Fast	1.249	0.301	4.151	1.002	0.016
	Control, Upper Arm, Fast	0.671	0.239	2.811	0.539	1.000
	ASD, Hand, Fast	0.978	0.301	3.249	0.785	0.448
	Control, Hand, Fast	1.434	0.253	5.679	1.151	8.427×10^{-6}
	ASD, Back, Fast	0.174	0.301	0.579	0.140	1.000
	Control, Back, Fast	0.337	0.253	1.334	0.270	1.000
ASD, Hand, Slow	Control, Hand, Slow	0.533	0.301	1.773	0.428	1.000
	ASD, Back, Slow	-0.202	0.239	-0.847	-0.162	1.000
	Control, Back, Slow	-0.461	0.301	-1.533	-0.370	1.000
	ASD, Ventral Forearm, Fast	0.225	0.264	0.853	0.181	1.000
	Control, Ventral Forearm, Fast	0.325	0.301	1.082	0.261	1.000
	ASD, Dorsal Forearm, Fast	0.175	0.264	0.663	0.141	1.000

	Control, Dorsal Forearm, Fast	0.336	0.301	1.117	0.270	1.000
	ASD, Upper Arm, Fast	0.773	0.264	2.926	0.620	1.000
	Control, Upper Arm, Fast	0.195	0.301	0.649	0.157	1.000
	ASD, Hand, Fast	0.501	0.250	2.008	0.402	1.000
	Control, Hand, Fast	0.958	0.301	3.184	0.769	0.552
	ASD, Back, Fast	-0.302	0.264	-1.144	-0.242	1.000
	Control, Back, Fast	-0.139	0.301	-0.463	-0.112	1.000
Control, Hand, Slow	ASD, Back, Slow	-0.736	0.301	-2.445	-0.590	1.000
	Control, Back, Slow	-0.995	0.228	-4.353	-0.798	0.006
	ASD, Ventral Forearm, Fast	-0.308	0.301	-1.025	-0.247	1.000
	Control, Ventral Forearm, Fast	-0.208	0.253	-0.824	-0.167	1.000
	ASD, Dorsal Forearm, Fast	-0.358	0.301	-1.191	-0.288	1.000
	Control, Dorsal Forearm, Fast	-0.197	0.253	-0.782	-0.158	1.000
	ASD, Upper Arm, Fast	0.239	0.301	0.795	0.192	1.000
	Control, Upper Arm, Fast	-0.338	0.253	-1.340	-0.272	1.000
	ASD, Hand, Fast	-0.032	0.301	-0.107	-0.026	1.000
	Control, Hand, Fast	0.425	0.239	1.778	0.341	1.000
	ASD, Back, Fast	-0.836	0.301	-2.777	-0.671	1.000
	Control, Back, Fast	-0.673	0.253	-2.663	-0.540	1.000
ASD, Back, Slow	Control, Back, Slow	-0.259	0.301	-0.861	-0.208	1.000
	ASD, Ventral Forearm, Fast	0.427	0.264	1.619	0.343	1.000
	Control, Ventral Forearm, Fast	0.528	0.301	1.754	0.423	1.000
	ASD, Dorsal Forearm, Fast	0.377	0.264	1.429	0.303	1.000
	Control, Dorsal Forearm, Fast	0.538	0.301	1.789	0.432	1.000
	ASD, Upper Arm, Fast	0.975	0.264	3.692	0.782	0.091
	Control, Upper Arm, Fast	0.397	0.301	1.321	0.319	1.000
	ASD, Hand, Fast	0.703	0.264	2.664	0.565	1.000
	Control, Hand, Fast	1.160	0.301	3.856	0.931	0.052
	ASD, Back, Fast	-0.100	0.250	-0.400	-0.080	1.000
	Control, Back, Fast	0.063	0.301	0.209	0.050	1.000
Control, Back, Slow	ASD, Ventral Forearm, Fast	0.686	0.301	2.281	0.551	1.000

	Control, Ventral Forearm, Fast	0.787	0.253	3.114	0.631	0.661
	ASD, Dorsal Forearm, Fast	0.636	0.301	2.115	0.511	1.000
	Control, Dorsal Forearm, Fast	0.797	0.253	3.156	0.640	0.581
	ASD, Upper Arm, Fast	1.234	0.301	4.100	0.990	0.020
	Control, Upper Arm, Fast	0.656	0.253	2.598	0.527	1.000
	ASD, Hand, Fast	0.962	0.301	3.199	0.772	0.528
	Control, Hand, Fast	1.419	0.253	5.619	1.139	1.173×10^{-5}
	ASD, Back, Fast	0.159	0.301	0.529	0.128	1.000
	Control, Back, Fast	0.322	0.239	1.348	0.258	1.000
ASD, Ventral Forearm, Fast	Control, Ventral Forearm, Fast	0.100	0.301	0.333	0.080	1.000
	ASD, Dorsal Forearm, Fast	-0.050	0.239	-0.210	-0.040	1.000
	Control, Dorsal Forearm, Fast	0.111	0.301	0.368	0.089	1.000
	ASD, Upper Arm, Fast	0.547	0.239	2.292	0.439	1.000
	Control, Upper Arm, Fast	-0.030	0.301	-0.100	-0.024	1.000
	ASD, Hand, Fast	0.276	0.239	1.156	0.222	1.000
	Control, Hand, Fast	0.733	0.301	2.436	0.588	1.000
	ASD, Back, Fast	-0.527	0.239	-2.207	-0.423	1.000
	Control, Back, Fast	-0.364	0.301	-1.211	-0.293	1.000
Control, Ventral Forearm, Fast	ASD, Dorsal Forearm, Fast	-0.150	0.301	-0.500	-0.121	1.000
	Control, Dorsal Forearm, Fast	0.011	0.228	0.046	0.008	1.000
	ASD, Upper Arm, Fast	0.447	0.301	1.486	0.359	1.000
	Control, Upper Arm, Fast	-0.130	0.228	-0.570	-0.105	1.000
	ASD, Hand, Fast	0.176	0.301	0.584	0.141	1.000
	Control, Hand, Fast	0.633	0.228	2.769	0.508	1.000
	ASD, Back, Fast	-0.627	0.301	-2.085	-0.504	1.000
	Control, Back, Fast	-0.465	0.228	-2.034	-0.373	1.000
ASD, Dorsal Forearm, Fast	Control, Dorsal Forearm, Fast	0.161	0.301	0.535	0.129	1.000
	ASD, Upper Arm, Fast	0.598	0.239	2.502	0.480	1.000
	Control, Upper Arm, Fast	0.020	0.301	0.067	0.016	1.000
	ASD, Hand, Fast	0.326	0.239	1.366	0.262	1.000
	Control, Hand, Fast	0.783	0.301	2.602	0.628	1.000

	ASD, Back, Fast	-0.477	0.239	-1.998	-0.383	1.000
	Control, Back, Fast	-0.314	0.301	-1.045	-0.252	1.000
Control, Dorsal Forearm, Fast	ASD, Upper Arm, Fast	0.437	0.301	1.451	0.350	1.000
	Control, Upper Arm, Fast	-0.141	0.228	-0.617	-0.113	1.000
	ASD, Hand, Fast	0.165	0.301	0.549	0.133	1.000
	Control, Hand, Fast	0.622	0.228	2.723	0.499	1.000
	ASD, Back, Fast	-0.638	0.301	-2.120	-0.512	1.000
	Control, Back, Fast	-0.475	0.228	-2.080	-0.381	1.000
ASD, Upper Arm, Fast	Control, Upper Arm, Fast	-0.577	0.301	-1.919	-0.463	1.000
	ASD, Hand, Fast	-0.271	0.239	-1.136	-0.218	1.000
	Control, Hand, Fast	0.186	0.301	0.617	0.149	1.000
	ASD, Back, Fast	-1.075	0.239	-4.499	-0.862	0.003
	Control, Back, Fast	-0.912	0.301	-3.031	-0.732	0.874
Control, Upper Arm, Fast	ASD, Hand, Fast	0.306	0.301	1.017	0.246	1.000
	Control, Hand, Fast	0.763	0.228	3.340	0.612	0.319
	ASD, Back, Fast	-0.497	0.301	-1.652	-0.399	1.000
	Control, Back, Fast	-0.334	0.228	-1.464	-0.268	1.000
ASD, Hand, Fast	Control, Hand, Fast	0.457	0.301	1.518	0.367	1.000
	ASD, Back, Fast	-0.803	0.239	-3.363	-0.645	0.295
	Control, Back, Fast	-0.641	0.301	-2.129	-0.514	1.000
Control, Hand, Fast	ASD, Back, Fast	-1.260	0.301	-4.188	-1.011	0.014
	Control, Back, Fast	-1.097	0.228	-4.803	-0.881	7.789×10^{-4}
ASD, Back, Fast	Control, Back, Fast	0.163	0.301	0.541	0.131	1.000

Note. Results are averaged over the levels of: Sex. SE- standard error of the coefficient; *t*- Student's *t*test.

Table C.3

Post Hoc Comparisons for the Body Location × Speed Interaction from the Repeated Measures ANOVA on NRS Other Ratings

		Mean Difference	SE	*t*	Cohen's *d*	p_{holm}
Ventral Forearm, Static	Dorsal Forearm, Static	-0.015	0.186	-0.079	-0.009	1.000
	Upper Arm, Static	-0.031	0.186	-0.168	-0.020	1.000
	Hand, Static	-1.174	0.186	-6.316	-0.757	4.417×10^{-8}
	Back, Static	-0.666	0.186	-3.585	-0.430	0.024
	Ventral Forearm, Slow	-0.808	0.196	-4.118	-0.521	0.003
	Dorsal Forearm, Slow	-0.658	0.213	-3.092	-0.424	0.122
	Upper Arm, Slow	-1.048	0.213	-4.927	-0.676	9.045×10^{-5}
	Hand, Slow	-0.230	0.213	-1.082	-0.149	1.000
	Back, Slow	-1.450	0.213	-6.817	-0.936	2.162×10^{-9}
	Ventral Forearm, Fast	-0.231	0.196	-1.175	-0.149	1.000
	Dorsal Forearm, Fast	-0.317	0.213	-1.492	-0.205	1.000
	Upper Arm, Fast	-0.333	0.213	-1.564	-0.215	1.000
	Hand, Fast	0.031	0.213	0.144	0.020	1.000
	Back, Fast	-1.195	0.213	-5.619	-0.771	2.658×10^{-6}
Dorsal Forearm, Static	Upper Arm, Static	-0.017	0.186	-0.089	-0.011	1.000
	Hand, Static	-1.159	0.186	-6.238	-0.748	7.073×10^{-8}
	Back, Static	-0.651	0.186	-3.506	-0.420	0.032
	Ventral Forearm, Slow	-0.794	0.213	-3.731	-0.512	0.015
	Dorsal Forearm, Slow	-0.643	0.196	-3.277	-0.415	0.070
	Upper Arm, Slow	-1.034	0.213	-4.859	-0.667	1.252×10^{-4}
	Hand, Slow	-0.216	0.213	-1.013	-0.139	1.000
	Back, Slow	-1.436	0.213	-6.749	-0.926	3.338×10^{-9}
	Ventral Forearm, Fast	-0.216	0.213	-1.015	-0.139	1.000
	Dorsal Forearm, Fast	-0.303	0.196	-1.542	-0.195	1.000
	Upper Arm, Fast	-0.318	0.213	-1.496	-0.205	1.000
	Hand, Fast	0.045	0.213	0.213	0.029	1.000
	Back, Fast	-1.181	0.213	-5.550	-0.762	3.833×10^{-6}
Upper Arm, Static	Hand, Static	-1.142	0.186	-6.148	-0.737	1.203×10^{-7}
	Back, Static	-0.635	0.186	-3.417	-0.410	0.043
	Ventral Forearm, Slow	-0.777	0.213	-3.653	-0.501	0.020
	Dorsal Forearm, Slow	-0.627	0.213	-2.946	-0.404	0.193
	Upper Arm, Slow	-1.017	0.196	-5.181	-0.656	2.739×10^{-5}
	Hand, Slow	-0.199	0.213	-0.935	-0.128	1.000
	Back, Slow	-1.419	0.213	-6.671	-0.916	5.458×10^{-9}
	Ventral Forearm, Fast	-0.199	0.213	-0.937	-0.129	1.000
	Dorsal Forearm, Fast	-0.286	0.213	-1.345	-0.185	1.000
	Upper Arm, Fast	-0.302	0.196	-1.537	-0.195	1.000
	Hand, Fast	0.062	0.213	0.291	0.040	1.000
	Back, Fast	-1.164	0.213	-5.472	-0.751	5.797×10^{-6}

Hand, Static	Back, Static	0.507	0.186	2.731	0.327	0.361
	Ventral Forearm, Slow	0.365	0.213	1.716	0.236	1.000
	Dorsal Forearm, Slow	0.516	0.213	2.423	0.333	0.829
	Upper Arm, Slow	0.125	0.213	0.588	0.081	1.000
	Hand, Slow	0.943	0.196	4.805	0.608	1.685×10^{-4}
	Back, Slow	-0.277	0.213	-1.302	-0.179	1.000
	Ventral Forearm, Fast	0.943	0.213	4.432	0.608	8.741×10^{-4}
	Dorsal Forearm, Fast	0.856	0.213	4.024	0.552	0.005
	Upper Arm, Fast	0.841	0.213	3.951	0.542	0.006
	Hand, Fast	1.204	0.196	6.134	0.777	1.589×10^{-7}
	Back, Fast	-0.022	0.213	-0.103	-0.014	1.000
Back, Static	Ventral Forearm, Slow	-0.142	0.213	-0.669	-0.092	1.000
	Dorsal Forearm, Slow	0.008	0.213	0.038	0.005	1.000
	Upper Arm, Slow	-0.382	0.213	-1.797	-0.247	1.000
	Hand, Slow	0.436	0.213	2.048	0.281	1.000
	Back, Slow	-0.784	0.196	-3.996	-0.506	0.006
	Ventral Forearm, Fast	0.435	0.213	2.047	0.281	1.000
	Dorsal Forearm, Fast	0.349	0.213	1.639	0.225	1.000
	Upper Arm, Fast	0.333	0.213	1.566	0.215	1.000
	Hand, Fast	0.697	0.213	3.275	0.449	0.070
	Back, Fast	-0.529	0.196	-2.697	-0.341	0.397
Ventral Forearm, Slow	Dorsal Forearm, Slow	0.150	0.186	0.810	0.097	1.000
	Upper Arm, Slow	-0.240	0.186	-1.292	-0.155	1.000
	Hand, Slow	0.578	0.186	3.112	0.373	0.115
	Back, Slow	-0.642	0.186	-3.456	-0.414	0.038
	Ventral Forearm, Fast	0.578	0.196	2.943	0.373	0.193
	Dorsal Forearm, Fast	0.491	0.213	2.308	0.317	1.000
	Upper Arm, Fast	0.476	0.213	2.235	0.307	1.000
	Hand, Fast	0.839	0.213	3.944	0.541	0.006
	Back, Fast	-0.387	0.213	-1.819	-0.250	1.000
Dorsal Forearm, Slow	Upper Arm, Slow	-0.390	0.186	-2.102	-0.252	1.000
	Hand, Slow	0.428	0.186	2.302	0.276	1.000
	Back, Slow	-0.793	0.186	-4.266	-0.511	0.002
	Ventral Forearm, Fast	0.427	0.213	2.008	0.276	1.000
	Dorsal Forearm, Fast	0.341	0.196	1.735	0.220	1.000
	Upper Arm, Fast	0.325	0.213	1.528	0.210	1.000
	Hand, Fast	0.689	0.213	3.236	0.444	0.077
	Back, Fast	-0.538	0.213	-2.526	-0.347	0.635
Upper Arm, Slow	Hand, Slow	0.818	0.186	4.404	0.528	9.561×10^{-4}
	Back, Slow	-0.402	0.186	-2.164	-0.259	1.000
	Ventral Forearm, Fast	0.818	0.213	3.844	0.528	0.010
	Dorsal Forearm, Fast	0.731	0.213	3.436	0.472	0.041
	Upper Arm, Fast	0.716	0.196	3.645	0.462	0.020
	Hand, Fast	1.079	0.213	5.072	0.696	4.452×10^{-5}

	Back, Fast	-0.147	0.213	-0.691	-0.095	1.000
Hand, Slow	Back, Slow	-1.220	0.186	-6.568	-0.787	9.238×10^{-9}
	Ventral Forearm, Fast	-3.982×10^{-4}	0.213	-0.002	-2.569×10^{-4}	1.000
	Dorsal Forearm, Fast	-0.087	0.213	-0.410	-0.056	1.000
	Upper Arm, Fast	-0.103	0.213	-0.482	-0.066	1.000
	Hand, Fast	0.261	0.196	1.329	0.168	1.000
	Back, Fast	-0.965	0.213	-4.537	-0.623	5.490×10^{-4}
Back, Slow	Ventral Forearm, Fast	1.220	0.213	5.733	0.787	1.417×10^{-6}
	Dorsal Forearm, Fast	1.133	0.213	5.326	0.731	1.253×10^{-5}
	Upper Arm, Fast	1.118	0.213	5.253	0.721	1.815×10^{-5}
	Hand, Fast	1.481	0.213	6.961	0.955	8.476×10^{-10}
	Back, Fast	0.255	0.196	1.299	0.165	1.000
Ventral Forearm, Fast	Dorsal Forearm, Fast	-0.087	0.186	-0.467	-0.056	1.000
	Upper Arm, Fast	-0.102	0.186	-0.550	-0.066	1.000
	Hand, Fast	0.261	0.186	1.406	0.169	1.000
	Back, Fast	-0.965	0.186	-5.193	-0.622	2.342×10^{-5}
Dorsal Forearm, Fast	Upper Arm, Fast	-0.015	0.186	-0.083	-0.010	1.000
	Hand, Fast	0.348	0.186	1.873	0.225	1.000
	Back, Fast	-0.878	0.186	-4.726	-0.566	2.247×10^{-4}
Upper Arm, Fast	Hand, Fast	0.364	0.186	1.957	0.234	1.000
	Back, Fast	-0.863	0.186	-4.643	-0.556	3.298×10^{-4}
Hand, Fast	Back, Fast	-1.226	0.186	-6.599	-0.791	7.628×10^{-9}

Note. Results are averaged over the levels of: Group and Sex. SE- standard error of the coefficient; *t* - Student's *t*test.

C.1. Within-Group Exploration in the ASD Sample.

To further explore individual variability within the autism spectrum disorder (ASD) group, we conducted additional analyses restricted to these participants only. These analyses aimed to examine potential sex differences and associations between questionnaire measures (TEAQ, BES, CBCL), intellectual coefficient (IC), and the touch perception task (NRS Self and NRS Other). Results are presented below.

Table C.4

Sex Differences in Questionnaire Scores and Touch Ratings

	t	df	*p*	Cohen's *d*	SE Cohen's *d*
CBCL Social Problems Direct Scoring	0.933	40	0.356	0.306	0.332
CBCL Social Problems Tipic Scoring	1.299	40	0.201	0.425	0.337
IC Scores	-0.948	33	0.350	-0.345	0.371
TEAQ FFT	-0.524	44	0.603	-0.165	0.316
TEAQ ChT	-0.276	44	0.784	-0.087	0.315
TEAQ ASC	1.556	44	0.127	0.489	0.327
TEAQ AUT	-1.414	44	0.164	-0.445	0.325
BES Cognitive Empathy	0.541	44	0.591	0.170	0.316
BES Affective Empathy	0.369	44	0.714	0.116	0.315
NRS Self	0.655	44	0.516	0.206	0.317
NRS Other	-0.273	44	0.786	-0.086	0.315

Note. Independent samples t-tests were conducted to investigate potential differences between males and females with ASD in TEAQ, BES, and CBCL subscale scores, IC scores, as well as in the NRS Self and NRS Other ratings; For the independent samples t-test Cohen's d was calculated to estimate effect sizes; t - Student's *t*-test; df - degrees of freedom; SE- standard error of the coefficient.

No significant sex differences were observed within the ASD group for any of the TEAQ, BES, CBCL subscales, IC scores, or NRS Self and Other ratings.

C.2. Sex Effects on NRS Self and Other.

Two repeated-measures ANOVAs were conducted with sex as a between-subject factor, and Skin Location and stroking Speed as within-subject factors, separately for NRS Self and NRS Other ratings. These analyses aimed to examine whether males and females with ASD responded differently to the vicarious touch task across conditions. The Greenhouse-Geisser correction was applied when the assumption of sphericity was violated and post-hoc paired comparisons were computed with Holm correction. Partial Eta Squared (η_p^2) and Cohen's d were calculated to estimate effect sizes.

C.2.1. NRS Self

Table C.5

Within Subjects Effects

Cases	Sphericity Correction	Sum of Squares	df	Mean Square	*F*	*p*	η^2	η_p^2
Skin Location	None	12.087	4.000	3.022	2.557	0.041	0.011	0.066
	Greenhouse-Geisser	12.087	2.844	4.250	2.557	0.062	0.011	0.066
Skin Location ✻ Sex	None	3.534	4.000	0.884	0.748	0.561	0.003	0.020
	Greenhouse-Geisser	3.534	2.844	1.243	0.748	0.520	0.003	0.020
Residuals	None	170.202	144.000	1.182				
	Greenhouse-Geisser	170.202	102.395	1.662				
Speed	None	25.043	2.000	12.522	5.038	0.009	0.023	0.123

	Greenhouse-Geisser	25.043	1.584	15.810	5.038	0.015	0.023	0.123
Speed ✻ Sex	None	8.669	2.000	4.335	1.744	0.182	0.008	0.046
	Greenhouse-Geisser	8.669	1.584	5.473	1.744	0.189	0.008	0.046
Residuals	None	178.969	72.000	2.486				
	Greenhouse-Geisser	178.969	57.024	3.138				
Skin Location ✻ Speed	None	34.760	8.000	4.345	5.388	2.499×10^{-6}	0.032	0.130
	Greenhouse-Geisser	34.760	4.320	8.046	5.388	2.962×10^{-4}	0.032	0.130
Skin Location ✻ Speed ✻ Sex	None	5.024	8.000	0.628	0.779	0.622	0.005	0.021
	Greenhouse-Geisser	5.024	4.320	1.163	0.779	0.550	0.005	0.021
Residuals	None	232.264	288.000	0.806				
	Greenhouse-Geisser	232.264	155.524	1.493				

Note. df - degrees of freedom.

Table C.6

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2	η_p^2
Sex	28.430	1	28.430	2.747	0.106	0.027	0.071
Residuals	372.525	36	10.348				

Note. df - degrees of freedom.

Table C.7

Post Hoc Comparisons - Speed

		Mean Difference	SE	t	p_{holm}
Static	Slow	-0.533	0.174	-3.061	0.009
	Fast	-0.140	0.174	-0.803	0.425
Slow	Fast	0.393	0.174	2.258	0.054

Note. SE- standard error of the coefficient; t - Student's t-test.

Table C.8

Post Hoc Comparisons - Skin Location ✻ Speed

		Mean Difference	SE	t	p_{holm}
Ventral Forearm, Static	Dorsal Forearm, Static	0.031	0.238	0.132	1.000
	Upper Arm, Static	0.047	0.238	0.199	1.000
	Hand, Static	-0.963	0.238	-4.044	0.006
	Back, Static	-0.225	0.238	-0.943	1.000
	Ventral Forearm, Slow	-0.771	0.264	-2.922	0.317
	Dorsal Forearm, Slow	-0.651	0.278	-2.345	1.000

	Upper Arm, Slow	-0.876	0.278	-3.152	0.160
	Hand, Slow	-0.636	0.278	-2.289	1.000
	Back, Slow	-0.838	0.278	-3.017	0.237
	Ventral Forearm, Fast	-0.411	0.264	-1.557	1.000
	Dorsal Forearm, Fast	-0.461	0.278	-1.659	1.000
	Upper Arm, Fast	0.137	0.278	0.492	1.000
	Hand, Fast	-0.135	0.278	-0.485	1.000
	Back, Fast	-0.938	0.278	-3.376	0.078
Dorsal Forearm, Static	Upper Arm, Static	0.016	0.238	0.068	1.000
	Hand, Static	-0.995	0.238	-4.176	0.004
	Back, Static	-0.256	0.238	-1.074	1.000
	Ventral Forearm, Slow	-0.802	0.278	-2.887	0.345
	Dorsal Forearm, Slow	-0.683	0.264	-2.589	0.792
	Upper Arm, Slow	-0.907	0.278	-3.265	0.112
	Hand, Slow	-0.667	0.278	-2.402	1.000
	Back, Slow	-0.869	0.278	-3.130	0.168
	Ventral Forearm, Fast	-0.442	0.278	-1.591	1.000
	Dorsal Forearm, Fast	-0.492	0.264	-1.866	1.000
	Upper Arm, Fast	0.105	0.278	0.379	1.000
	Hand, Fast	-0.166	0.278	-0.597	1.000
	Back, Fast	-0.969	0.278	-3.489	0.053
Upper Arm, Static	Hand, Static	-1.011	0.238	-4.243	0.003
	Back, Static	-0.272	0.238	-1.142	1.000
	Ventral Forearm, Slow	-0.818	0.278	-2.945	0.295
	Dorsal Forearm, Slow	-0.699	0.278	-2.516	0.940
	Upper Arm, Slow	-0.923	0.264	-3.500	0.053
	Hand, Slow	-0.683	0.278	-2.460	1.000
	Back, Slow	-0.886	0.278	-3.187	0.143
	Ventral Forearm, Fast	-0.458	0.278	-1.649	1.000
	Dorsal Forearm, Fast	-0.508	0.278	-1.830	1.000
	Upper Arm, Fast	0.089	0.264	0.338	1.000
	Hand, Fast	-0.182	0.278	-0.655	1.000
	Back, Fast	-0.985	0.278	-3.547	0.044
Hand, Static	Back, Static	0.739	0.238	3.102	0.179
	Ventral Forearm, Slow	0.193	0.278	0.693	1.000
	Dorsal Forearm, Slow	0.312	0.278	1.122	1.000
	Upper Arm, Slow	0.088	0.278	0.315	1.000
	Hand, Slow	0.327	0.264	1.241	1.000
	Back, Slow	0.125	0.278	0.450	1.000
	Ventral Forearm, Fast	0.553	0.278	1.989	1.000
	Dorsal Forearm, Fast	0.502	0.278	1.808	1.000
	Upper Arm, Fast	1.100	0.278	3.959	0.009
	Hand, Fast	0.829	0.264	3.142	0.166
	Back, Fast	0.025	0.278	0.091	1.000

Back, Static	Ventral Forearm, Slow	-0.546	0.278	-1.966	1.000
	Dorsal Forearm, Slow	-0.427	0.278	-1.537	1.000
	Upper Arm, Slow	-0.651	0.278	-2.344	1.000
	Hand, Slow	-0.411	0.278	-1.481	1.000
	Back, Slow	-0.614	0.264	-2.326	1.000
	Ventral Forearm, Fast	-0.186	0.278	-0.670	1.000
	Dorsal Forearm, Fast	-0.236	0.278	-0.851	1.000
	Upper Arm, Fast	0.361	0.278	1.300	1.000
	Hand, Fast	0.090	0.278	0.324	1.000
	Back, Fast	-0.713	0.264	-2.705	0.582
Ventral Forearm, Slow	Dorsal Forearm, Slow	0.119	0.238	0.501	1.000
	Upper Arm, Slow	-0.105	0.238	-0.441	1.000
	Hand, Slow	0.135	0.238	0.566	1.000
	Back, Slow	-0.067	0.238	-0.283	1.000
	Ventral Forearm, Fast	0.360	0.264	1.365	1.000
	Dorsal Forearm, Fast	0.310	0.278	1.115	1.000
	Upper Arm, Fast	0.907	0.278	3.266	0.112
	Hand, Fast	0.636	0.278	2.289	1.000
	Back, Fast	-0.167	0.278	-0.602	1.000
Dorsal Forearm, Slow	Upper Arm, Slow	-0.224	0.238	-0.942	1.000
	Hand, Slow	0.016	0.238	0.065	1.000
	Back, Slow	-0.187	0.238	-0.784	1.000
	Ventral Forearm, Fast	0.241	0.278	0.867	1.000
	Dorsal Forearm, Fast	0.191	0.264	0.723	1.000
	Upper Arm, Fast	0.788	0.278	2.837	0.397
	Hand, Fast	0.517	0.278	1.860	1.000
	Back, Fast	-0.286	0.278	-1.031	1.000
Upper Arm, Slow	Hand, Slow	0.240	0.238	1.007	1.000
	Back, Slow	0.038	0.238	0.158	1.000
	Ventral Forearm, Fast	0.465	0.278	1.674	1.000
	Dorsal Forearm, Fast	0.415	0.278	1.493	1.000
	Upper Arm, Fast	1.012	0.264	3.839	0.015
	Hand, Fast	0.741	0.278	2.668	0.634
	Back, Fast	-0.062	0.278	-0.224	1.000
Hand, Slow	Back, Slow	-0.202	0.238	-0.849	1.000
	Ventral Forearm, Fast	0.225	0.278	0.811	1.000
	Dorsal Forearm, Fast	0.175	0.278	0.630	1.000
	Upper Arm, Fast	0.773	0.278	2.781	0.465
	Hand, Fast	0.501	0.264	1.901	1.000
	Back, Fast	-0.302	0.278	-1.087	1.000
Back, Slow	Ventral Forearm, Fast	0.427	0.278	1.538	1.000
	Dorsal Forearm, Fast	0.377	0.278	1.358	1.000
	Upper Arm, Fast	0.975	0.278	3.509	0.050
	Hand, Fast	0.703	0.278	2.532	0.910

	Back, Fast	-0.100	0.264	-0.378	1.000
Ventral Forearm, Fast	Dorsal Forearm, Fast	-0.050	0.238	-0.210	1.000
	Upper Arm, Fast	0.547	0.238	2.298	1.000
	Hand, Fast	0.276	0.238	1.159	1.000
	Back, Fast	-0.527	0.238	-2.213	1.000
Dorsal Forearm, Fast	Upper Arm, Fast	0.598	0.238	2.509	0.940
	Hand, Fast	0.326	0.238	1.369	1.000
	Back, Fast	-0.477	0.238	-2.003	1.000
Upper Arm, Fast	Hand, Fast	-0.271	0.238	-1.139	1.000
	Back, Fast	-1.075	0.238	-4.512	8.789×10^{-4}
Hand, Fast	Back, Fast	-0.803	0.238	-3.373	0.077

Note. SE- standard error of the coefficient; *t* - Student's *t*-test.

C.2.2. NRS Other

Table C.9

Within Subjects Effects

Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2	η_p^2,
Skin Location	None	30.063	4.000	7.516	4.761	0.001	0.018	0.117
	Greenhouse-Geisser	30.063	2.635	11.408	4.761	0.006	0.018	0.117
Skin Location ✻ Sex	None	4.255	4.000	1.064	0.674	0.611	0.003	0.018
	Greenhouse-Geisser	4.255	2.635	1.615	0.674	0.551	0.003	0.018
Residuals	None	227.297	144.000	1.578				
	Greenhouse-Geisser	227.297	94.868	2.396				
Speed	None	13.000	2.000	6.500	1.730	0.185	0.008	0.046
	Greenhouse-Geisser	13.000	1.717	7.570	1.730	0.190	0.008	0.046
Speed ✻ Sex	None	2.589	2.000	1.295	0.344	0.710	0.002	0.009
	Greenhouse-Geisser	2.589	1.717	1.508	0.344	0.677	0.002	0.009
Residuals	None	270.601	72.000	3.758				
	Greenhouse-Geisser	270.601	61.822	4.377				
Skin Location ✻ Speed	None	52.169	8.000	6.521	5.662	1.092×10^{-6}	0.032	0.136
	Greenhouse-Geisser	52.169	4.965	10.506	5.662	7.466×10^{-5}	0.032	0.136
Skin Location ✻ Speed ✻ Sex	None	5.622	8.000	0.703	0.610	0.769	0.003	0.017
	Greenhouse-Geisser	5.622	4.965	1.132	0.610	0.691	0.003	0.017
Residuals	None	331.710	288.000	1.152				
	Greenhouse-Geisser	331.710	178.755	1.856				

Note. df - degrees of freedom.

Table C.10

Between Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2	η_p^2
Sex	3.382	1	3.382	0.172	0.681	0.002	0.005
Residuals	708.668	36	19.685				

Note. df - degrees of freedom.

Table C.11

Post Hoc Comparisons - Skin Location

		Mean Difference	SE	t	p_{holm}
Ventral Forearm	Dorsal Forearm	-0.118	0.175	-0.670	1.000
	Upper Arm	-0.054	0.175	-0.305	1.000
	Hand	-0.352	0.175	-2.007	0.326
	Back	-0.656	0.175	-3.741	0.003
Dorsal Forearm	Upper Arm	0.064	0.175	0.365	1.000
	Hand	-0.235	0.175	-1.337	0.733
	Back	-0.539	0.175	-3.070	0.020
Upper Arm	Hand	-0.299	0.175	-1.702	0.511
	Back	-0.602	0.175	-3.435	0.007
Hand	Back	-0.304	0.175	-1.733	0.511

Note. SE - standard error of the coefficient; t - Student's t-test.

Table C.12

Post Hoc Comparisons - Skin Location ✻ Speed

		Mean Difference	SE	t	p_{holm}
Ventral Forearm, Static	Dorsal Forearm, Static	0.026	0.275	0.094	1.000
	Upper Arm, Static	-0.162	0.275	-0.588	1.000
	Hand, Static	-1.290	0.275	-4.690	3.843×10^{-4}
	Back, Static	-0.345	0.275	-1.253	1.000
	Ventral Forearm, Slow	-0.483	0.313	-1.543	1.000
	Dorsal Forearm, Slow	-0.647	0.326	-1.985	1.000
	Upper Arm, Slow	-0.582	0.326	-1.787	1.000
	Hand, Slow	-0.303	0.326	-0.930	1.000
	Back, Slow	-1.064	0.326	-3.265	0.111
	Ventral Forearm, Fast	-0.014	0.313	-0.045	1.000
	Dorsal Forearm, Fast	-0.228	0.326	-0.701	1.000
	Upper Arm, Fast	0.087	0.326	0.266	1.000
	Hand, Fast	0.040	0.326	0.123	1.000
	Back, Fast	-1.056	0.326	-3.243	0.117
Dorsal Forearm, Static	Upper Arm, Static	-0.188	0.275	-0.682	1.000
	Hand, Static	-1.316	0.275	-4.784	2.499×10^{-4}
	Back, Static	-0.370	0.275	-1.347	1.000
	Ventral Forearm, Slow	-0.508	0.326	-1.561	1.000
	Dorsal Forearm, Slow	-0.673	0.313	-2.150	1.000

	Upper Arm, Slow	-0.608	0.326	-1.866	1.000
	Hand, Slow	-0.329	0.326	-1.009	1.000
	Back, Slow	-1.090	0.326	-3.345	0.086
	Ventral Forearm, Fast	-0.040	0.326	-0.122	1.000
	Dorsal Forearm, Fast	-0.254	0.313	-0.813	1.000
	Upper Arm, Fast	0.061	0.326	0.186	1.000
	Hand, Fast	0.014	0.326	0.043	1.000
	Back, Fast	-1.082	0.326	-3.322	0.092
Upper Arm, Static	Hand, Static	-1.128	0.275	-4.102	0.005
	Back, Static	-0.183	0.275	-0.665	1.000
	Ventral Forearm, Slow	-0.321	0.326	-0.985	1.000
	Dorsal Forearm, Slow	-0.485	0.326	-1.489	1.000
	Upper Arm, Slow	-0.420	0.313	-1.344	1.000
	Hand, Slow	-0.141	0.326	-0.433	1.000
	Back, Slow	-0.902	0.326	-2.769	0.503
	Ventral Forearm, Fast	0.148	0.326	0.453	1.000
	Dorsal Forearm, Fast	-0.067	0.326	-0.205	1.000
	Upper Arm, Fast	0.248	0.313	0.794	1.000
	Hand, Fast	0.202	0.326	0.619	1.000
	Back, Fast	-0.895	0.326	-2.746	0.530
Hand, Static	Back, Static	0.945	0.275	3.437	0.061
	Ventral Forearm, Slow	0.807	0.326	2.478	1.000
	Dorsal Forearm, Slow	0.643	0.326	1.975	1.000
	Upper Arm, Slow	0.708	0.326	2.173	1.000
	Hand, Slow	0.987	0.313	3.156	0.156
	Back, Slow	0.226	0.326	0.694	1.000
	Ventral Forearm, Fast	1.276	0.326	3.917	0.011
	Dorsal Forearm, Fast	1.062	0.326	3.259	0.112
	Upper Arm, Fast	1.377	0.326	4.225	0.003
	Hand, Fast	1.330	0.313	4.253	0.003
	Back, Fast	0.234	0.326	0.717	1.000
Back, Static	Ventral Forearm, Slow	-0.138	0.326	-0.424	1.000
	Dorsal Forearm, Slow	-0.302	0.326	-0.927	1.000
	Upper Arm, Slow	-0.238	0.326	-0.729	1.000
	Hand, Slow	0.042	0.326	0.128	1.000
	Back, Slow	-0.719	0.313	-2.300	1.000
	Ventral Forearm, Fast	0.331	0.326	1.015	1.000
	Dorsal Forearm, Fast	0.116	0.326	0.357	1.000
	Upper Arm, Fast	0.431	0.326	1.324	1.000
	Hand, Fast	0.385	0.326	1.181	1.000
	Back, Fast	-0.712	0.313	-2.276	1.000
Ventral Forearm, Slow	Dorsal Forearm, Slow	-0.164	0.275	-0.596	1.000
	Upper Arm, Slow	-0.099	0.275	-0.362	1.000
	Hand, Slow	0.180	0.275	0.654	1.000

	Back, Slow	-0.581	0.275	-2.113	1.000
	Ventral Forearm, Fast	0.469	0.313	1.498	1.000
	Dorsal Forearm, Fast	0.254	0.326	0.780	1.000
	Upper Arm, Fast	0.569	0.326	1.747	1.000
	Hand, Fast	0.523	0.326	1.604	1.000
	Back, Fast	-0.574	0.326	-1.761	1.000
Dorsal Forearm, Slow	Upper Arm, Slow	0.065	0.275	0.235	1.000
	Hand, Slow	0.344	0.275	1.250	1.000
	Back, Slow	-0.417	0.275	-1.517	1.000
	Ventral Forearm, Fast	0.633	0.326	1.942	1.000
	Dorsal Forearm, Fast	0.418	0.313	1.337	1.000
	Upper Arm, Fast	0.733	0.326	2.251	1.000
	Hand, Fast	0.687	0.326	2.108	1.000
	Back, Fast	-0.410	0.326	-1.258	1.000
Upper Arm, Slow	Hand, Slow	0.279	0.275	1.015	1.000
	Back, Slow	-0.482	0.275	-1.751	1.000
	Ventral Forearm, Fast	0.568	0.326	1.744	1.000
	Dorsal Forearm, Fast	0.354	0.326	1.086	1.000
	Upper Arm, Fast	0.669	0.313	2.138	1.000
	Hand, Fast	0.622	0.326	1.910	1.000
	Back, Fast	-0.474	0.326	-1.456	1.000
Hand, Slow	Back, Slow	-0.761	0.275	-2.766	0.503
	Ventral Forearm, Fast	0.289	0.326	0.887	1.000
	Dorsal Forearm, Fast	0.074	0.326	0.229	1.000
	Upper Arm, Fast	0.389	0.326	1.196	1.000
	Hand, Fast	0.343	0.313	1.096	1.000
	Back, Fast	-0.753	0.326	-2.313	1.000
Back, Slow	Ventral Forearm, Fast	1.050	0.326	3.222	0.124
	Dorsal Forearm, Fast	0.835	0.326	2.564	0.887
	Upper Arm, Fast	1.150	0.326	3.531	0.046
	Hand, Fast	1.104	0.326	3.388	0.075
	Back, Fast	0.007	0.313	0.024	1.000
Ventral Forearm, Fast	Dorsal Forearm, Fast	-0.214	0.275	-0.779	1.000
	Upper Arm, Fast	0.101	0.275	0.366	1.000
	Hand, Fast	0.054	0.275	0.197	1.000
	Back, Fast	-1.042	0.275	-3.790	0.017
Dorsal Forearm, Fast	Upper Arm, Fast	0.315	0.275	1.145	1.000
	Hand, Fast	0.268	0.275	0.976	1.000
	Back, Fast	-0.828	0.275	-3.010	0.238
Upper Arm, Fast	Hand, Fast	-0.047	0.275	-0.169	1.000
	Back, Fast	-1.143	0.275	-4.156	0.004
Hand, Fast	Back, Fast	-1.096	0.275	-3.986	0.008

Note. SE - standard error of the coefficient; *t*- Student's *t*test.

The repeated-measures ANOVA results conducted within the ASD group revealed similar patterns to those observed in the full sample (ASD and neurotypical controls).

C.3. Correlational Analyses

Pearson's correlations were performed to explore associations between NRS Self and Other ratings and questionnaire measures (TEAQ, BES, CBCL, IC). Fisher's z was calculated to estimate effect sizes, and p-values were adjusted using the False Discovery Rate (FDR) correction to account for multiple comparisons.

Table C.13

Pearson's Correlations

Variable		TEAQ_FFT	TEAQ_ChT	TEAQ_ASC	TEAQ_AUT	BES_CogEmp	BES_AffEmp	CBCL_SP_PD	CBCL_SP_PT	IC_scores	NRS_S	NRS_O
1. TEAQ_FFT	Pearson's r	—										
	p-value	—										
	Effect size (Fisher's z)	—										
	SE Effect size	—										
2. TEAQ_ChT	Pearson's r	0.406	—									
	p-value	0.005	—									
	Effect size (Fisher's z)	0.431	—									
	SE Effect size	0.152	—									
3. TEAQ_ASC	Pearson's r	0.458	−0.024	—								
	p-value	0.001	0.872	—								
	Effect size (Fisher's z)	0.494	−0.024	—								
	SE Effect size	0.152	0.152	—								
4. TEAQ_AUT	Pearson's r	0.040	−0.195	0.048	—							
	p-value	0.794	0.195	0.754	—							
	Effect size (Fisher's z)	0.040	−0.197	0.048	—							
	SE Effect size	0.152	0.152	0.152	—							
5. BES_CogEmp	Pearson's r	0.231	0.035	0.117	−0.046	—						
	p-value	0.123	0.819	0.440	0.762	—						
	Effect size (Fisher's z)	0.235	0.035	0.117	−0.046	—						
	SE Effect size	0.152	0.152	0.152	0.152	—						
6. BES_AffEmp	Pearson's r	0.512	0.210	0.254	0.123	0.266	—					
	p-value	2.769×10^{-4}	0.161	0.089	0.415	0.074	—					
	Effect size (Fisher's z)	0.565	0.213	0.260	0.124	0.272	—					
	SE Effect size	0.152	0.152	0.152	0.152	0.152	—					
7. CBCL_SP_PD	Pearson's r	−0.010	0.185	−0.120	0.188	0.012	0.168	—				
	p-value	0.955	0.241	0.449	0.232	0.941	0.286	—				
	Effect size (Fisher's z)	−0.010	0.187	−0.121	0.191	0.012	0.170	—				
	SE Effect size	0.183	0.160	0.160	0.160	0.160	0.160	—				
8. CBCL_SP_PT	Pearson's r	3.820×10^{-4}	0.128	−0.103	0.162	−0.062	0.167	0.959	—			
	p-value	0.998	0.420	0.518	0.306	0.697	0.290	1.503×10^{-23}	—			
	Effect size (Fisher's z)	3.820×10^{-4}	0.129	−0.103	0.163	−0.062	0.169	1.935	—			
	SE Effect size	0.183	0.160	0.160	0.160	0.160	0.160	0.160	—			
9. IC_scores	Pearson's r	0.089	0.279	0.012	−0.107	−0.090	−0.168	−0.010	3.820×10^{-4}	—		
	p-value	0.609	0.105	0.945	0.541	0.607	0.334	0.955	0.998	—		
	Effect size (Fisher's z)	0.090	0.286	0.012	−0.107	−0.090	−0.170	−0.010	3.820×10^{-4}	—		
	SE Effect size	0.177	0.177	0.177	0.177	0.177	0.177	0.183	0.183	—		
10. NRS_S	Pearson's r	0.205	−0.217	0.524	−0.145	0.220	0.091	−0.344	−0.338	−0.060	—	
	p-value	0.171	0.148	1.865×10^{-4}	0.337	0.141	0.546	0.026	0.029	0.732	—	
	Effect size (Fisher's z)	0.208	−0.220	0.582	−0.146	0.224	0.092	−0.358	−0.351	−0.060	—	
	SE Effect size	0.152	0.152	0.152	0.152	0.152	0.152	0.160	0.160	0.177	—	
11. NRS_O	Pearson's r	0.526	0.023	0.565	0.153	0.183	0.212	−0.254	−0.284	−0.004	0.630	—
	p-value	1.722×10^{-4}	0.878	4.329×10^{-5}	0.310	0.222	0.157	0.104	0.068	0.980	2.743×10^{-6}	—
	Effect size (Fisher's z)	0.585	0.023	0.640	0.154	0.186	0.215	−0.260	−0.292	−0.004	0.741	—
	SE Effect size	0.152	0.152	0.152	0.152	0.152	0.152	0.160	0.160	0.177	0.152	—

NRS Self using the FDR correction:
TEAQ FFT: p_{fdr} = 0.2565000
TEAQ ChT: p_{fdr} = 0.2565000
TEAQ ASC: p_{fdr} = 0.0180000
TEAQ AUT: p_{fdr} = 0.4332857
BES cognitive: p_{fdr} = 0.2565000
BES affective: p_{fdr} = 0.6142500
CBCL Social Problems, direct punctuation: p_{fdr} = 0.0870000
CBCL Social Problems, tipic punctuation: p_{fdr} = 0.0870000
IC: p_{fdr} = 0.7320000

NRS Other using the FDR correction:
TEAQ FFT: p_{fdr} = 0.0090000
TEAQ ChT: p_{fdr} = 0.9800000
TEAQ ASC: p_{fdr} = 0.0003600
TEAQ AUT: p_{fdr} = 0.3985714
BES cognitive: p_{fdr} = 0.3330000
BES affective: p_{fdr} = 0.2826000
CBCL Social Problems, direct punctuation: p_{fdr} = 0.2340000
CBCL Social Problems, tipic punctuation: p_{fdr} = 0.2040000
IC: p_{fdr} = 0.9800000

Pearson correlations with the ASD group revealed similar patterns to those observed in the full sample (ASD and neurotypical controls).

C.4. Regression Analyses by Sex within the ASD Group

Multiple linear regression models were conducted to examine whether individual differences in questionnaire measures (TEAQ, BES, CBCL, and IC), as well as sex, predicted NRS Self and NRS Other ratings in the ASD sample.

C.4.1. NRS Self

Table C.14
Model Summary

					Durbin-Watson		
Model	R	R^2	Adjusted R^2	RMSE	Autocorrelation	Statistic	*p*
H_0	0.000	0.000	0.000	0.906	0.245	1.305	0.038
H_1	0.659	0.435	0.178	0.821	0.105	1.601	0.181

Table C.15
ANOVA

Model		Sum of Squares	df	Mean Square	*F*	*p*
H_1	Regression	11.412	10	1.141	1.692	0.146
	Residual	14.835	22	0.674		
	Total	26.247	32			

Note. df - degrees of freedom.

Table C.16

Coefficients

Model		Unstandardized	Standard Error	Standardized[a]	*t*	*p*
H_0	(Intercept)	4.068	0.158		25.804	5.464×10^{-23}
H_1	(Intercept)	3.725	2.832		1.315	0.202
	TEAQ FFT	-0.027	0.292	-0.026	-0.092	0.928
	TEAQ ChT	-0.190	0.305	-0.144	-0.624	0.539
	TEAQ ASC	0.482	0.244	0.416	1.979	0.061
	TEAQ AUT	-0.392	0.223	-0.347	-1.760	0.092
	BES CogEmp	0.195	0.506	0.082	0.386	0.703
	BES AffEmp	0.351	0.497	0.174	0.705	0.488
	CBCL SP PD	-0.023	0.126	-0.117	-0.181	0.858
	CBCL SP PT	-0.007	0.038	-0.113	-0.177	0.861
	IC Scores	-0.003	0.009	-0.056	-0.299	0.768
	Sex (M)	0.395	0.379		1.042	0.309

Note. t - Student's t-test.

C.4.2. NRS Other

Table C.17

Model Summary

					Durbin-Watson		
Model	R	R^2	Adjusted R^2	RMSE	Autocorrelation	Statistic	*p*
H_0	0.000	0.000	0.000	0.906	0.245	1.305	0.038
H_1	0.730	0.532	0.320	0.877	0.035	1.909	0.660

Table C 18

ANOVA

Model		Sum of Squares	df	Mean Square	*F*	*p*
H_1	Regression	19.287	10	1.929	2.505	0.035
	Residual	16.939	22	0.770		
	Total	36.226	32			

Note. df - degrees of freedom.

Table C.19

Coefficients

Model		Unstandardized	Standard Error	Standardized[a]	*t*	*p*
H_0	(Intercept)	3.466	0.185		18.714	8.500×10^{-19}
H_1	(Intercept)	-0.370	3.026		-0.122	0.904
	TEAQ FFT	0.379	0.312	0.312	1.214	0.238
	TEAQ ChT	-0.048	0.326	-0.031	-0.148	0.883
	TEAQ ASC	0.394	0.260	0.290	1.515	0.144
	TEAQ AUT	-7.614×10^{-4}	0.238	-5.746×10^{-4}	-0.003	0.997
	BES CogEmp	0.620	0.541	0.221	1.146	0.264
	BES AffEmp	0.090	0.531	0.038	0.170	0.866
	CBCL SP PD	-0.068	0.134	-0.297	-0.505	0.618
	CBCL SP PT	0.003	0.040	0.043	0.074	0.942
	IC Scores	-0.004	0.009	-0.065	-0.377	0.710
	Sex (M)	0.522	0.405		1.288	0.211

Note. t - Student's *t*-test.

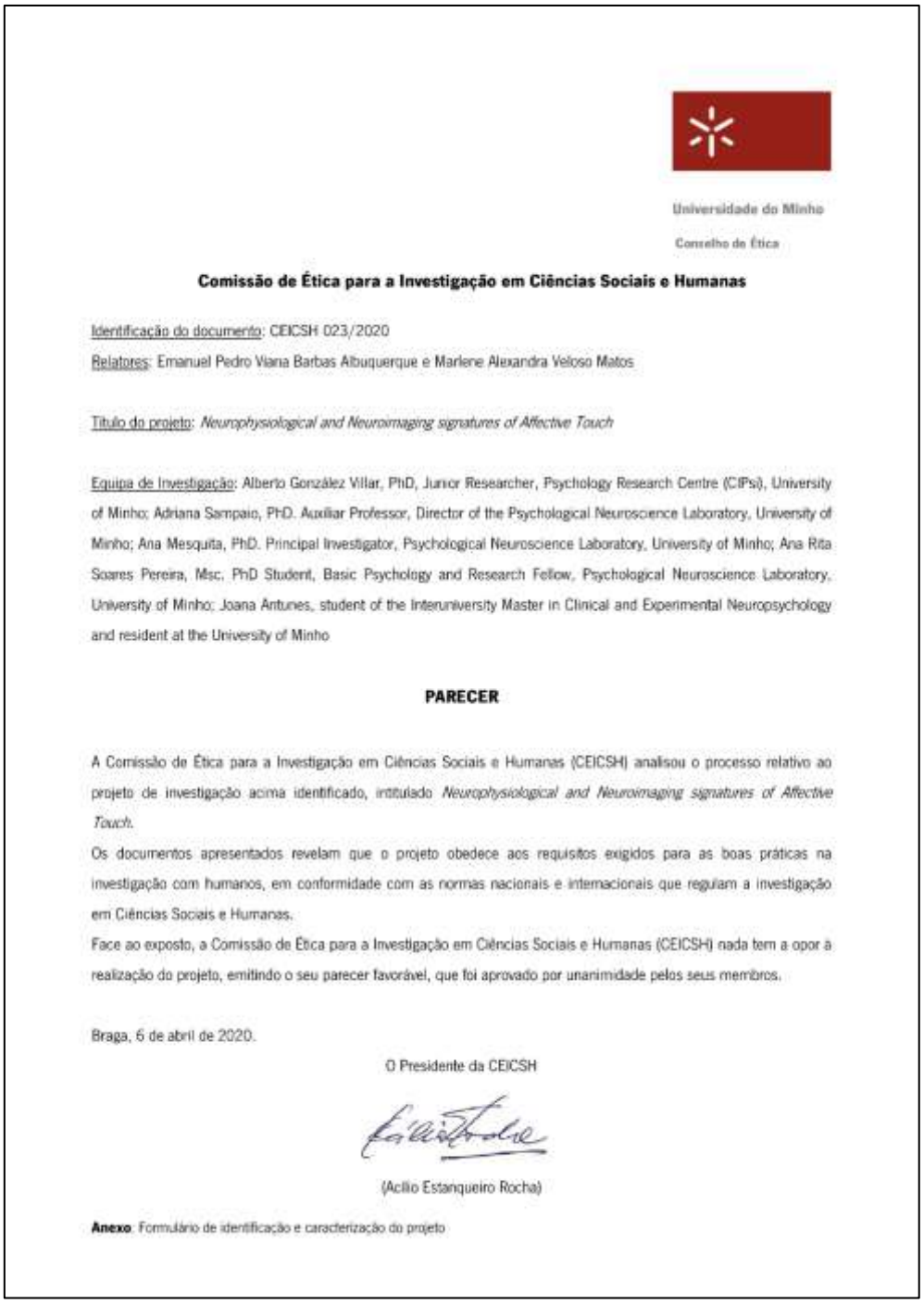
Multiple linear regression models with the ASD group also revealed similar patterns to those observed in the full sample (ASD and neurotypical controls).

C.5. Conclusion

No significant sex differences were observed within the ASD group. Overall, the patterns of results were consistent with those found in the full sample, reinforcing the robustness of the main findings.

Appendix D. Project Ethical Approval

The studies presented in Chapter 2, 3, 4, and 5 in the current dissertation were approved by the Ethics Committee for Human and Social Sciences of the University of Minho (CEICSH 023/2020), as shown below.



Universidade do Minho

Conselho de Ética

Comissão de Ética para a Investigação em Ciências Sociais e Humanas

Identificação do documento: CEICSH 023/2020

Relatores: Emanuel Pedro Viana Barbas Albuquerque e Marlene Alexandra Veloso Matos

Título do projeto: *Neurophysiological and Neuroimaging signatures of Affective Touch*

Equipa de Investigação: Alberto González Villar, PhD, Junior Researcher, Psychology Research Centre (CIPs), University of Minho; Adriana Sampaio, PhD. Auxiliar Professor, Director of the Psychological Neuroscience Laboratory, University of Minho; Ana Mesquita, PhD. Principal Investigator, Psychological Neuroscience Laboratory, University of Minho; Ana Rita Soares Pereira, Msc. PhD Student, Basic Psychology and Research Fellow, Psychological Neuroscience Laboratory, University of Minho; Joana Antunes, student of the Interuniversity Master in Clinical and Experimental Neuropsychology and resident at the University of Minho

PARECER

A Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) analisou o processo relativo ao projeto de investigação acima identificado, intitulado *Neurophysiological and Neuroimaging signatures of Affective Touch*.

Os documentos apresentados revelam que o projeto obedece aos requisitos exigidos para as boas práticas na investigação com humanos, em conformidade com as normas nacionais e internacionais que regulam a investigação em Ciências Sociais e Humanas.

Face ao exposto, a Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) nada tem a opor à realização do projeto, emitindo o seu parecer favorável, que foi aprovado por unanimidade pelos seus membros.

Braga, 6 de abril de 2020.

O Presidente da CEICSH

(Acílio Estanqueiro Rocha)

Anexo: Formulário de identificação e caracterização do projeto