Health in your hands: Multi-method insights into the physiological and psychological outcomes of real and vicarious interpersonal touch in older adults

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Table of Contents

List of Tables

List of Figures

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Abstract

Interpersonal touch is recognised for its comforting effects, promoting both health and well-being, and aiding in stress regulation. However, most research on touch has focused on younger adults and single health markers, leaving considerable gaps in understanding the impact of touch for multi-systemic health, especially in groups at risk of touch absence. In this thesis, four studies investigate the health benefits of interpersonal touch for older adults, including the factors that may be most important and the role of a vicarious touch as a possible intervention. Findings from the National Social Life, Health, and Aging Project (NSHAP) found that frequent touch with romantic partners was associated with improved neuroendocrine health in cross-sectional analyses and better metabolic and cardiovascular health in longitudinal analyses. In contrast, touch with other close individuals showed no comparable associations. In examining vicarious hugs, we observed that while longer durations of observation increased autonomic arousal, indicated by pupil dilations, they did not protect from stress. Furthermore, different types of touch, including CT-optimal stroking, hugging, and handshakes, shared with individuals of varying emotional closeness (close individual, stranger, and vicarious) were associated with varying physiological and neural responses. CT-optimal stroking showed the most context-independent reductions in heart rate and increased in theta power. Overall, neural findings suggest that theta oscillatory increases may be a marker of both tactile observation and sensation in older adults, while beta and alpha are responsible for differences in attentional processing, but also the hedonic properties of touch in older adults. These insights could be used to support public health strategies aimed at improving physiological well-being in older adults, with further scope for the use of vicarious stroking as a low-cost intervention for older adults in social care or clinical settings.

1. General Introduction

Touch is a fundamental aspect of human interaction and perception, shaping our experiences and social navigation. Beyond its role in sensory perception, touch mediates various affective and social functions (Cascio et al., 2019). As a means of expressing love, empathy, and solidarity, interpersonal touch promotes well-being and social bonds. Research demonstrates that touch-based therapies aid trauma recovery (Phelan, 2009), strengthen parent-child relationships (Field, 2010), and improve patient care (Anderson & Taylor, 2011), emphasising the role of touch as a form of therapeutic non-verbal communication. Moreover, studies links interpersonal touch to prosocial behaviours; even brief contact can promote cooperation and generosity (Guéguen & Fischer-Lokou, 2002, 2003; Joule & Guéguen, 2007). For example, touch is associated with a greater willingness to donate to charity (Kurzban, 2001) and participate in surveys (Hornik & Ellis, 1988). Additionally, touch provides stress relief (Grewen et al., 2003), beyond the benefits of interpersonal proximity (Nelson & Panksepp, 1998). Thus, given its several benefits, this understudied sense is both an interesting an important avenue of research.

What is Known About Touch Across the Lifespan

Touch is the earliest sensory system to develop, emerging between 4 to 7 weeks of gestation, and remains the most advanced at birth. Interpersonal touch is a vital form of non-verbal communication that enables human connection even before language skills develop (Burgoon et al., 1996; Routasalo, 1999). Studies by Della Longa and colleagues (2021; 2019) show that infants as young as four months old learn unfamiliar faces more effectively when their faces are gently stroked by a parent, emphasising the importance of parental touch in early social, emotional, and cognitive development (Beltrán et al., 2020; Field, 2010). Moreover, touch interactions constitute 65% of mother-infant communication, and have been found reduce both early behavioural and physiological stress responses in infants (Feldman et al., 2010; Stack & Muir, 1990).

Adequate tactile stimulation is essential; its absence can result in growth impairments, cognitive delays, and increased susceptibility to illness (Frank et al., 1996). Physical contact with caregivers fosters attachment security and emotional bonds, influencing cognitive and neurobehavioural development by shaping social brain networks (Ainsworth et al., 2015; Anisfeld et al., 1990; Brauer et al., 2016; Feldman & Eidelman, 2003; Feldman et al., 2002). Even brief increases in daily touch, up to 20 minutes, significantly improve developmental outcomes, underscoring its foundational role in early life (Casler, 1965; Hopper & Pinneau, 1957). The type of touch also matters; gentle stroking induces more positive responses in infants than static touch. Gentle stroking at skin temperatures and a velocity of 1-10 cm/s (Ackerley, Backlund Wasling, et al., 2014) is thought to activate fibres that reliably activate neural pathways associated with affective and reward-related brain regions, this is termed CT-optimal touch (Gordon et al., 2013). Interestingly, parents often naturally use CT-optimal stimulation speeds during touch (Croy et al., 2016; Jean & Stack, 2009; Stack & Muir, 1990). From infancy to childhood, touch remains important for expressing positive emotions, inducing positive affect, and strengthening brain areas responsible for social cognition, especially when shared within the family (Bai et al., 2016; Brauer et al., 2016; Burgdorf & Panksepp, 2001; Ishiyama & Brecht, 2016).

In adulthood, individuals both give and receive touch regularly in their close relationships (Anderson & McCormack, 2015). Being touched and touching others is a central element of social interaction and social relationships (Field, 2010). Touch in adulthood reduces feelings of social exclusion, promotes well-being, and conveys emotions and motivations (Debrot et al., 2013; von Mohr et al., 2017). Even brief touch can have a significant impact; research shows that young adults reported feeling more socially connected after receiving a simple touch on the shoulder from an experimenter (Koole et al., 2014). Moreover, it plays a pivotal role in the formation and maintenance of close interpersonal bonds, especially in romantic relationships (Bell et al., 1987), where touch fosters psychological closeness, attraction, and relationship satisfaction (Brennan et al., 1998; Gulledge et al., 2003; Mehrabian, 1969). As a nonverbal mechanism, touch uniquely distinguishes romantic partners from friends (Guerrero, 1997), yet enhances positive emotional states in both types of relationships (Coan et al., 2006; Sbarra & Hazan, 2008). Beyond strengthening bonds, touch also serves a coregulatory function, alleviating distress and improving mood during emotional challenges (Debrot et al., 2014).

While touch is the first sense we develop, it is also the last one we retain (Green, 2017). In older adulthood, the role of touch shifts as changes in physical and social dynamics alter tactile experiences. Although discriminative touch abilities decline with age, the perception of pleasantness from interpersonal touch, such as CT-optimal touch, tends to increase (Sehlstedt et al., 2016). Older adults often describe touch using more emotional language and rate touch as more rewarding compared to younger individuals, possibly due to reduced touch frequency, which may heighten its emotional impact (Guest et al., 2014; Ishikura et al., 2024). Although findings are mixed for the perception of touch among individuals who experience touch absence (Sailer & Ackerley, 2019). Despite a possible greater appreciation for touch, older adults may be less likely to share touch relative to their younger counterparts (Upenieks & Schafer, 2022), possibly due to smaller social networks, higher rates of living alone, and increased social isolation (ONS, 2021; Pedell et al., 2010; Pino et al., 2014; Scharf & de Jong Gierveld, 2008). Although touch continues to hold therapeutic value for this demographic, particularly in clinical settings. For example, touch was associated with improvements in symptoms of depression in institutionalised depressed older adults (Buschmann et al., 1999) and communication in institutionalised confused older women (Langland & Panicucci, 1982).

Additionally, tactile therapies like massage have demonstrated effectiveness in alleviating depression and agitation in individuals with dementia (Watt et al., 2021; Watt et al., 2019). Robotic touch interventions have also been found to elicit positive emotional and physiological responses in older adults, highlighting its potential as a substitute for human contact in socially isolated individuals (Ishikura et al., 2024). Overall, although older adults may be at a heightened risk of touch absence and generally place a greater value on touch, the specific characteristics and behaviours associated with touch within this demographic remain unclear. Furthermore, it is uncertain whether the therapeutic benefits of touch extend to non-clinical older adults.

Touch Absence

Touch absence refers to a lack of physical contact, which can manifest in two ways: as an unwanted deficiency, where individuals desire more touch than they can access, or as a consciously chosen state (Green & Moran, 2021). Individuals desire touch to different degrees; when individuals have more positive attitudes and experiences towards touch, they want to experience it more (Von Mohr & Fotopoulou, 2018; Von Mohr et al., 2021b). Although Galinsky et al (2014) reported that most men and women report that gentle touch, hugging, and cuddling appeal to them. Nonetheless, touch absence has been shown to have negative consequences, including increased feelings of loneliness (Heatley Tejada et al., 2020), anxiety (Floyd, 2014), depression (Stein & Sanfilipo, 1985), and worse wellbeing (Debrot et al., 2021).

Coan’s (2008) Social Baseline Theory (SBT) posits that humans have an innate expectation for social support due to the need for care during infancy. SBT suggests that an individual's baseline state is inherently social, and that social interactions are essential for emotional regulation. Thus, when social connections are limited, individuals may struggle to effectively regulate their emotions (Coan, 2010). During the COVID-19 pandemic, strict social distancing measures exacerbated this issue by significantly limiting physical contact and disrupting people's tactile interactions with others, especially for those living alone (Armitage & Nellums, 2020). In the UK, the mental health impacts of these restrictions were profound, with loneliness and living alone identified as key risk factors for heightened anxiety and depression during the early pandemic months (Chandola et al., 2022; Fancourt et al., 2021).

Studies investigating touch during COVID-19 revealed several interesting findings regarding touch absence. Burleson et al. (2022) found that while social distancing during led to a decrease in interpersonal touch, this was only among individuals not cohabiting with a romantic partner. For those cohabiting with their partners, social distancing was associated with an increase in touch, possibly explained by a compensatory behaviour or increased opportunity for affection between partners (Evans et al., 2020; Maner et al., 2007). This suggests that the unavailability of a romantic partner, or living alone might be risk factors for touch absence. Additionally, Von Mohr et al. (2021b) found that the longer individuals practiced social distancing, the more their desire for touch intensified, especially with close individuals (partners and family members), even if these were the individuals that touch was shared most with (Von Mohr et al., 2021b). However, touch absence is not solely a pandemic-related issue. The continuous increase in human lifespan signifies ample changes in social structures and interactions, and older adults who live alone may be particularly vulnerable to the loss of receiving touch.

There is a positive association between age and loneliness (Donovan et al., 2017), living alone, and social isolation (Savikko et al., 2005; Victor et al., 2002). Furthermore, increased mortality is reported among older adults with less frequency of contact with other people and social integration (Seeman et al., 1993). Research indicates that approximately 34% of women and 21% of men aged over 60 in the United states live alone (Ausubel, 2020), a trend that mirrors findings in the UK, where single-person households comprised between 22.8% and 33.6% of the population in 2020 (ONS, 2021). The rise in the number of people living alone is largely concentrated in older age groups (ONS, 2021). With life expectancy increasing, an estimated one in five people will be over 60 by 2050 (United Nations., 2019), the number of older adults experiencing touch absence is likely to grow. Thus, older adults face unique challenges that heighten their risk of experiencing touch absence.

While it might be assumed that the negative effects of loneliness could be alleviated by positive touch experiences, this relationship remains underexplored in existing literature (Noone & McKenna-Plumley, 2022; Victor, 2021). For example, individuals reporting higher levels of touch deprivation showed more negative perceptions of touch even when it occurred at CT-optimal velocities (Sailer & Ackerley, 2019). In contrast, a study by Heatley Tejada et al. (2020) found that single adults reported higher levels of neglect compared to those in relationships. However, physical touch from another person reduced these feelings to levels similar to those reported by coupled individuals. This suggests that touch may serve as an important environmental cue that encourages individuals to seek social connection (Cacioppo et al., 2014). Social determinants of health and quality of life in old age include strong social networks and high levels of social support (Berkman et al., 2014), which protect from various causes of morbidity and mortality. Despite findings indicating that touch absence is associated with negative outcomes, and that older adults may be at a heightened risk, the correlates of interpersonal touch in older adult populations, and the factors that are most conductive to the benefits of interpersonal touch in this group are under investigated.

Emotional Closeness

Research on touch across the lifespan reveals that emotional closeness plays a critical role in shaping the effects of touch. In early life, studies primarily examine interactions between child and caregiver, while studies in adulthood largely focus on romantic partners. This likely stems from their central role in adult life and their function as primary sources of emotional and physical support, where touch served as a key form of expressing affection and connection (Grewen et al., 2005; M. Diamond, 2000). Evidence shows that touch between romantic partners yields significant psychological and physiological benefits, including reduced blood pressure (Grewen et al., 2003), lower cortisol levels (Ditzen et al., 2007), and decreased anxiety (Coan et al., 2006). For example, hand-holding between partners enhances neural synchrony and alleviates pain (Goldstein et al., 2018), similar to effects observed between infants and their mothers during touch (Nguyen et al., 2021). Partner touch has also been linked to reduced stress, increased-self-esteem, and greater resilience during stressful situations (Jakubiak & Feeney, 2019), with relationship quality accounting up to 16.8% of this stress relief (Liu et al., 2021). Across cultures, touch from romantic partners is generally more acceptable than from other close relationships, further highlighting its unique role in adult life (Suvilehto et al., 2015).

Although romantic relationships typically involve deeper emotional connections, non-romantic touch still effectively fosters emotional bonding and support. This indicates that the benefits of touch extend beyond romantic partners to other trusted sources. In friendships, touch often served various functions, such as signalling attention and affection (Floyd & Voloudakis, 1999a, 1999b). Family members, in particular, express a broader range of emotions through touch than touch with strangers (Pisano et al., 1986; Suvilehto et al., 2015; Thompson & Hampton, 2011). Direct comparisons between touch from romantic partners and other close individuals remains limited. Some findings suggest that by simply having a partner in close proximity, rather than a friend, reduces threat-related activity in the amygdala over time (Morriss et al., 2019). Furthermore, evidence suggests romantic touch is more effective at reducing stress and enhancing positive emotions than touch from friends or strangers (Coan et al., 2006; Kreuder et al., 2017). For instance, hand-holding by a romantic partner can alleviate pain, whereas touch from friends or strangers often lacks this effect (Floyd et al., 2018). However, research also indicates that touch from healthcare professionals or acquaintances can provide similar physiological benefits, highlighting the importance of the context and the relationship's nature in shaping the perception of touch (Packheiser et al., 2024b).

Touch from strangers has mixed effects. It is often perceived as uncomfortable or intrusive (Sussman & Rosenfeld, 1978) and can increase physiological arousal during stress (Debrot et al., 2024), potentially due to its interpretation as a sign of sexual interest or dominance (Dolinski, 2010). For example, touch from an experimenter may lower heart rate while simultaneously raising skin conductance, indicating both calming and arousing effects (Vrana & Rollock, 1998). In some contexts, touch from strangers can have positive outcomes, such as increasing trust (Burgoon et al., 1992; Hertenstein et al., 2009), reducing cortisol levels during stress (Dreisoerner et al., 2021), and alleviating existential concerns (Koole et al., 2014). Additionally, touch from healthcare providers has been shown to improve sleep, blood pressure, respiratory rate and pain in medical settings (Papathanassoglou & Mpouzika, 2012).

Sex differences also play a role; women are generally more receptive to non-sexual touch from strangers than men (Hertenstein et al., 2006), while men in Western cultures tend to avoid same-sex touch with acquaintances (Crawford, 1994). Additionally, touch from opposite-sex strangers is often rated as pleasant by men but unpleasant by women (Heslin &

Alper, 1983). For women, the context significantly influences their response to touch, they tend to respond more positively in professional settings and more negatively when touched by an opposite-sex stranger outside of those contexts (Martin, 2012). Neuropsychological evidence also shows that contextual factors influence the sensory experience of touch, with variations in the primary somatosensory cortex depending on the perceived identity of the toucher (Gazzola et al., 2012). Even in children, friendly touch from an experimenter has been shown to increase self-regulation, like delaying gratification (Leonard et al., 2014). In educational settings, positive touch from teachers can increase on-task behaviour and reduce disruptions in young children (Wheldall et al., 1986). These findings suggest that although touch from strangers may not be as universally accepted as touch from close individuals, it can still have beneficial effects depending on the context.

Studies that directly compare touch from romantic partners versus strangers consistently show that partner touch is more effective at relieving pain and stress and is generally perceive as more pleasant (Coan et al., 2017; Coan et al., 2006; Floyd et al., 2018; Kreuder et al., 2017; Kreuder et al., 2019). This effect likely stems from the greater emotional intimacy and intensity inherent in romantic relationships, leading to stronger psychological and physiological benefits. Touch from partners also occurs more frequently and elicits stronger emotional responses than touch from strangers (Beßler et al., 2020; Xu et al., 2023). Even imagining touch from a partner is rated more positively than imagined touch from a stranger (Krahé et al., 2023). However, while partner touch significantly reduces threat responses in the brain, touch from strangers can still provide physiological benefits, such as reduced heart rate or increased skin conductance, indicating both calming and arousing effects (Vrana & Rollock, 1998). For example, holding a partner’s hand during stressful situations leads to a greater reduction in neural threat responses compared to holding a stranger’s hand, although both produce some benefit (Coan et al., 2006). Additionally, touch from familiar individuals and healthcare professionals may offer comparable health benefits, depending on the context (Packheiser et al., 2024b). Notably, CT-optimal touch produces positive effects regardless of whether the touch comes from a close individual (Triscoli, Croy, Olausson, et al., 2017) or a stranger (Kirsch et al., 2018). It remains unclear if these patterns apply to older adults, who pay perceive touch differently depending on the emotional closeness of the toucher. These findings underscore the complexity of touch perception, which varies depending on the emotional closeness to the toucher and the situational context.

Touch and Stress

Stress is defined as a real or perceived threat to an individual's psychological or physiological well-being (McEwen, 2013). It triggers a coordinated response across multiple body systems, primarily involving the autonomic nervous system (ANS) and the hypothalamic-pituitary-adrenal (HPA) axis, to manage these challenges. The ANS has two main branches: the sympathetic nervous system (SNS), which prepares the body for a 'fight-or-flight' response, and the parasympathetic nervous system (PNS), which promotes relaxation and recovery. Stress can be categorised into two forms: acute stress, which is short-term and typically resolves quickly, and chronic stress, which persists over time and can have more severe health implications (McEwen & Stellar, 1993). Acute stress initiates the body's immediate reaction to a threat by activating the sympathetic branch of the ANS, specifically the SNS (Herman et al., 2020). This activation triggers the sympathetic-adrenal-medullary (SAM) axis, leading to the rapid release of catecholamine's like adrenaline (epinephrine) and noradrenaline (norepinephrine). These hormones increase heart rate, blood pressure, and breathing rate, preparing the body for a 'fight-or-flight' response (Ulrich-Lai & Herman, 2009). Simultaneously, the HPA axis is engaged to manage longer-term stress responses. This process begins when the stressor is evaluated by brain regions, including the amygdala, hypothalamus, and the prefrontal cortex, which initiate the HPA axis cascade

(McEwen & Gianaros, 2011). Upon activation, the hypothalamic paraventricular nucleus releases corticotropin-releasing hormone (CRH) and arginine-vasopressin, stimulating the pituitary gland to produce adrenocorticotropic hormone (ACTH). ACTH prompts the adrenal cortex to produce glucocorticoids, primarily cortisol, which mobilises energy stores and regulates the immune response to help the body cope with prolonged stress (De Kloet et al., 2005). While this acute stress response is essential for survival, chronic activation of these systems, driven by recurrent or long-lasting stressors, can lead to harmful effects (McEwen, 1998; Sapolsky, 2021).

Unlike acute stress, which resolves once the immediate threat subsides, chronic stress results in sustained physiological changes that can significantly impact health and well-being. Central to understanding chronic stress is the concept of allostasis, which refers to the body's ability to maintain stability through adaptation to stressors (Sterling & Eyer, 1988). This adaptive process involves whole-body changes rather than focusing solely on specific biomarkers (Schulkin, 2003). Over time, repeated or long-lasting activation of the stress response results in allostatic load, representing the cumulative physiological toll on the body (McEwen & Stellar, 1993). Allostatic load describes the "wear and tear" on body systems, particularly involving the SNS and HPA axis. High allostatic load is linked to adverse health outcomes, such as cardiovascular diseases, metabolic disorders, cognitive decline, and increased mortality risk (Goldman et al., 2006; Seeman et al., 2001). The allostatic load model outlines three stages: (1) activation of primary mediators, such as stress hormones in response to acute stress, (2) the effects of long-term stress on metabolic, cardiovascular, and immune systems, and (3) allostatic overload, which heightens the risk of disease (Leahy & Crews, 2012; Seeman et al., 2001). Chronic over-activation of the SAM axis (releasing catecholamines) and HPA axis (releasing glucocorticoids) can lead to systemic overcompensation, increasing vulnerability to stress-related diseases (Lupien et al., 2015).

Evaluating these multi-system interactions helps identify individuals at risk of adverse health outcomes due to allostatic load (McEwen, 2000). Emerging evidence also suggests that touch may help mitigate or protect against the effects of allostatic load.

When individuals perceive a threat, they instinctively seek proximity to close others, particularly romantic partners, who can help reduce stress through social support (Cohen, 2004; Feeney, 2004; Mikulincer et al., 2003). Social support has been shown to attenuate stress responses across various physiological systems, including the ANS and HPA axis (Berkman & Syme, 1979; Heinrichs et al., 2003; Medalie & Goldbourt, 1976). Touch plays a critical role in this process, signalling social support and influencing stress regulation both directly and indirectly (Feldman et al., 2010; Heiman et al., 2011). Interpersonal touch activates the PNS, leading to reductions in heart rate, blood pressure, and cortisol levels, which collectively dampen the stress response (Ditzen et al., 2007). Touch also elevates levels of oxytocin, often referred to as the “bonding hormone”. This neuropeptide not only facilitates social bonding but also downregulates the HPA axis, reducing cortisol levels and promoting relaxation (Heinrichs et al., 2003; Uvnäs Moberg et al., 2020; Rakita et al., 2020). Research indicates that the cumulative effect of regular and repeated touch is more effective in enhancing oxytocin release than a single exposure (Light et al., 2005), further supporting the role of touch in stress mitigation.

Empirical evidence underscores the powerful role of touch in buffering stress. For example, Coan et al. (2006) found that married women experienced reduced neural activation in stress-related brain areas when holding their partner’s hand during a pain threat, emphasising the impact of touch on acute stress. Ditzen et al (2007) demonstrated that a brief session of physical touch, such as a neck and shoulder massage from a partner before a stress-inducing task, led to greater regulation of heart rate and cortisol responses compared to verbal support in women, indicating that touch is a more potent stress modulator than other forms of support. The influence of touch extends beyond acute stress to long-term health benefits. Studies show that individuals who engage in frequent interpersonal touch with close others have lower baseline cortisol levels and reduced cardiovascular reactivity to stressors, indicating a more resilient stress response system (Ditzen & Heinrichs, 2014; Light et al., 2005). This cumulative effect likely promotes long-term health by decreasing physiological costs associated with allostatic load and enhancing the body's ability to return to baseline after stress.

Animal studies highlight the importance of early physical contact in regulating stress-related systems, with maternal separation linked to long-term HPA axis disruptions (Levine, 2005). In humans, increased touch from a partner during stressful situations correlates with lower stress levels, higher self-esteem, and a greater sense of control over stressors (Jakubiak & Feeney, 2019). Interestingly, even in the absence of a close person, recalling past touch experiences can activate mental representations of support, helping to mitigate stress (Mikulincer et al., 2002). However, these benefits seem restricted to memories of touch from close individuals, suggesting that emotional closeness can influence stress responses. Despite its therapeutic potential, much of the evidence on touch's impact on stress comes from laboratory-based studies focussed primarily on romantic couples, and often overlooking the broader interdependence of physiological systems.

Importantly, chronic stress and the resulting dysregulation of physiological systems can accelerate ageing and increase disease risk. The MacArthur Studies found that individuals with high allostatic load scores were at greater risk of death (Karlamangla et al., 2006), while a longitudinal study in Taiwanese older adults revealed that allostatic load could serve as an early indicator for future health decline (Goldman et al., 2006). Research indicates that increasing age is associated with a higher benefit through touch for systolic blood pressure, although this may be attributed to higher basal blood pressure with increasing age, it may also indicate a role for touch in promoting healthy ageing (Packheiser et al., 2024b). Furthermore, longitudinal findings in older adults suggest that increased frequency of touch is associated with lower likelihood of chronic inflammation five years later (Thomas & Kim, 2021). Thus, the physiological health benefits of touch may be multi-systemic, and have prolonged effects in older adults. However, longitudinal associations are scarce, and investigation of multi-system dysregulation caused by touch absence in older adults is missing from existing literature.

Vicarious Touch

Vicarious touch could be a valuable tool for individuals with limited physical contact, such as older adults. Vicarious touch occurs when observing touch triggers neural and sensory responses similar to those activated during direct physical contact (Haans & IJsselsteijn, 2009). According to the Embodied Simulation Theory, this effect involves the brain mapping others' tactile experiences using its own motor, somatosensory, and visceromotor systems (Gallese & Ebisch, 2013). This simulation process is mediated by mirror neuron systems that respond both to experiencing and observing touch, a mechanism originally identified in macaques and later confirmed in humans (Keysers & Gazzola, 2009; Morrison et al., 2004; Rizzolatti et al., 2001). In humans, these neural circuits enable empathy by internally recreating others' sensations, allowing observers to understand touch as if they were feeling it themselves (Bellard et al., 2023; Keysers et al., 2010; Vachon-Presseau et al., 2012). Functional neuroimaging consistently shows activation of the dorsal posterior insula during the observation of CT-optimal touch, indicating a similar hedonic response to both direct and vicarious touch experiences (Björnsdotter & Olausson, 2011). Observing interpersonal touch not only enhances feelings of sociability and reduced isolation but also increases electroencephalographic (EEG) activity, highlighting the emotional impact of vicarious touch (Campagnoli et al., 2015). Moreover, observing touch activates neural pathways in the primary and secondary somatosensory cortices, reflecting a deep empathic engagement with others' tactile experiences (Blakemore et al., 2005; Ebisch et al., 2011). EEG studies further support these findings, showing that somatosensory-evoked potentials (SEPs) are influenced by both direct touch and its observation, reinforcing the concept of sensory mirroring in the brain (Bufalari et al., 2007; Pisoni et al., 2018; Rigato, Bremner, et al., 2019).

If observing touch can produce regulatory and well-being effects similar to real touch, vicarious touch interventions could be utilised as an alternative touch intervention. For instance, watching human-to-human or human-to-pet interactions has been linked to reduced subjective stress and increased calmness, indicating its therapeutic potential (Kirsch et al., 2024). However, the physiological impact of vicarious touch is not yet fully understood. While some studies suggest that observing touch can influence skin conductance and heart rate, these effects seem to depend on the context and emotional relevance of the touch (Adler & Gillmeister, 2019; Fusaro et al., 2016). For example, Fusaro et al (2016) found that painful vicarious touch increased galvanic skin response (GSR), while pleasant touch showed no significant difference from neutral touch, underscoring the importance of stimulus salience. Research on other physiological markers, like heart rate (HR) and heart rate variability (HRV), is still emerging but shows promise. One study found a reduction in HR following vicarious experiences of both pain and CT-optimal touch, suggesting a calming effect akin to that of direct touch (Fusaro et al., 2016). Similarly, increased pupil dilation in response to observing pain indicates an empathic reaction, engaging autonomic processes similar to those involved in real touch (Azevedo et al., 2013; Chiesa et al., 2015). Thus, while vicarious touch holds potential for enhancing emotional well-being in those lacking physical contact, further research is needed to better understand its physiological effects.

Full-body vicarious touch combines sensorimotor and socio-affective elements, with its processing strongly influenced by the emotional context of the touch (Schirmer & McGlone, 2019). Emotionally meaningful touches, like caressing or slapping, elicit stronger activation in the primary and secondary somatosensory cortices compared to neutral touches, highlighting the brain's sensitivity to emotionally charged stimuli (Ebisch et al., 2011). Facial electromyography (EMG) studies further reveal that CT-optimal stroking, leads to decreased frowning and increased smiling, indicating a positive emotional response (Pawling et al., 2017; Ree et al., 2019). The emotional impact of vicarious touch intensifies when the touch is perceived as occurring on the observer's own body, emphasising the role of self-relatedness (Cardini et al., 2011). Viewing touch from a first-person perspective, rather than a third-person view, activates the somatosensory cortex more strongly, enhancing the sense of bodily ownership (Saxe et al., 2006). This effect is reinforced by findings that first-person perspectives increase the illusion of ownership over virtual limbs and amplify neural responses to human, as opposed to non-human, touch (Adler & Gillmeister, 2019; Fusaro et al., 2016). Moreover, event-related potentials (ERPs) indicate stronger neural responses when observing touch on one's own face versus another's, underscoring the significance of self-relatedness in these experiences (Adler et al., 2016). Similarly, Rigato, Bremner, et al. (2019) found differential ERPs between first-person and third-person observations of touch on a hand, indicating an anatomical mapping for touch in the first-person perspective at P45, and a specular mapping in third-person at P100. Although the role of perspective in full-body vicarious interactions remains uncertain, perspective and exposure duration likely play crucial roles in shaping these effects. Most studies have focused on CT-optimal versus non-CT-optimal forearm stroking, with vicarious touch generally perceived as more pleasant at CT-optimal velocities (Bellard et al., 2022; Bellard et al., 2023; Devine et al., 2020; Haggarty et al., 2021; Walker et al., 2017). However, wider real-world touch experiences, such as hugs are understudied, highlighting the need to explore a wider range of contextual factors and different types of touch, that influence the perception and emotional impact of vicarious touch.

The effectiveness of vicarious touch appears to decline with age, as older adults often show reduced tactile sensitivity and empathy-related responses to observed touch, likely due to age-related changes in brain structure and emotion processing (Gillmeister et al., 2017; Kalisch et al., 2009). These alterations in brain function and reduced sensorimotor coordination may weaken the neural representation of observed touch, diminishing the emotional impact (Kalisch et al., 2009). Additionally, impaired emotion perception in older adults could further limit their empathetic responses to vicarious touch (Ruffman et al., 2008; Yang & Banissy, 2016). Although vicarious touch holds promise for delivering emotional and physiological benefits similar to direct touch, its effectiveness in older populations remains uncertain.

The Somatosensory System

The skin is the body's oldest and largest sense organ, equipped with a complex network of fibres that are responsible for processing both cutaneous (skin-based) and proprioceptive (muscle and joint) sensations (Gottlieb, 1971). When the skin undergoes deformation from touch, receptors transmit information about the touch to the brain (McGlone & Reilly, 2010). Interestingly, a distinct channel exists for pleasant touch, which plays a crucial role in emotional and social interactions (McGlone & Reilly, 2010). These are low-threshold, unmyelinated C-tactile mechanoreceptors (CT-fibres) (Nordin, 1990). CT-fibres respond optimally to slow, caress-like touches at a skin temperature of around 32° and a velocity of 1-10 cm/s (Ackerley, Backlund Wasling, et al., 2014). They are particularly dense in hairy skin areas, and stimulation of these regions reliably activates neural pathways associated with affective and reward-related brain regions, this is termed CT-optimal touch (Gordon et al., 2013).

In contrast, faster or slower touch velocities produce suboptimal CT responses, leading to a lower perception of pleasantness (Ackerley, Carlsson, et al., 2014; Ackerley, Saar, et al., 2014; Löken et al., 2009; Nordin, 1990). The subjective pleasantness experience during CT-optimal touch follows an inverted U-shaped response pattern when plotted against different touch velocities, with peak responses occurring within the optimal range (Ackerley, Carlsson, et al., 2014; Löken et al., 2009). CT-optimal touch is believed to have evolved to support social bonding and attachment, playing a crucial role in forming and maintaining close interpersonal relationships (McGlone et al., 2014). For example, people are more likely to use CT-optimal touch when interacting with loved ones, such as partners or children, compared to when touching inanimate objects or less familiar individuals (Croy et al., 2016).

Pleasant touch sensations are complemented by discriminative touch, which is primarily mediated by low-threshold mechanoreceptors, which determine the firing of rapidly conducting myelinated A-beta fibres (Aβ-fibres) (Björnsdotter et al., 2010), providing detailed information about the location and intensity of touch stimuli. Discriminative touch predominantly activates the primary somatosensory cortex, responsible for processing precise tactile information, while affective touch engages regions like the posterior insula, orbitofrontal cortex, anterior cingulate cortex, and amygdala, which are involved in emotional and reward processing (Björnsdotter et al., 2010; McGlone et al., 2014; Morrison, 2016a). Both forms of touch are integrated within the secondary somatosensory cortex, reflecting the overlap between tactile sensation and emotional response. This neural integration highlights the importance of touch not only as a sensory experience but also as a fundamental mechanism for emotional communication (Walker & McGlone, 2013).

Research shows that the density of tactile receptors in the skin decreases with age (Chang et al., 2004; Gøransson et al., 2004). This decline in receptor density leads to a reduced sensitivity to discriminative touch, manifesting as a decline in tactile acuity and sensitivity in older adults (Stevens & Choo, 1996; Stevens & Patterson, 1995; Thornbury & Mistretta, 1981; Zingaretti et al., 2019). However, despite the general decline in tactile sensitivity, older adults still perceive CT-targeted stimuli as more pleasant than non-optimal touch, with ratings of pleasantness for affective touch even increasing with age (Sehlstedt et al., 2016). These findings suggest that while discriminative touch sensitivity diminishes over time, the affective qualities of touch remain resilient and may continue to play a significant role in emotional well-being throughout ageing.

Unlike the CT-optimal touch, deep pressure touch may not primarily involve CT-fibres, but is embedded in several nearly universal forms of interpersonal touch, including hugging, cuddling, and massage (Case et al., 2021). Instead, it is mediated by pressure-sensitive receptors located deeper in muscle and connective tissues, which remain responsive even after the skin has been anesthetised (Graven-Nielsen et al., 2004). Evidence from animal studies has identified pressure-sensitive afferents in the skeletal muscle and tendons (Corey et al., 2011; Hoheisel et al., 2005; Mense & Meyer, 1985), it has been proposed that receptors such as these may play a role in conveying the sensory and pleasant experience of deep pressure (Case et al., 2021). One potential mechanism for the benefits of deep pressure touch involved the activation of dermal and subdermal pressure receptors innervated by vagal afferent fibres. These fibres project to the vagal nucleus of the solitary tract, which plays a crucial role in autonomic nervous system regulation, ultimately leading to relaxation and a calming effect (Diego & Field, 2009; Kandel et al., 2000). This connection suggests that deep pressure touch might elicit a physiological response that promotes relaxation by stimulating the parasympathetic nervous system via these pathways (McGlone & Reilly, 2010).

Although the majority of existing research focuses on the therapeutic benefits of CT-optimal touch, recent findings indicate that deep pressure touch, even when applied mechanically without interpersonal interaction, can produce effects similar to CT-optimal stroking, including comparable touch pleasantness ratings, increased calmness, and similar brain activation patterns (Case et al., 2021). Despite these parallels in the benefits of deep pressure touch, such as hugs, and CT-optimal stroking, direct comparisons between these types of touch are still lacking in the current literature.

Neural Bases for Encoding Touch

While touch is increasingly recognised for its role in regulating emotions and building social bonds (Brauer et al., 2016; Field, 2010; Suvilehto et al., 2015), its neural mechanisms have only recently gained attention. Sensory information from the skin is processed in the primary (SI) and secondary (SII) somatosensory cortices, where body surfaces are mapped contralaterally. Signals reach SI somatotopically (Maldjian et al., 1999), while SII, along the lateral sulcus, integrates touch with other sensory inputs, such as vision (Maeda et al., 1999; McGlone et al., 2002). The insula cortex then links this sensory information to emotional centres in the frontal lobe, connecting touch with affective responses (Augustine, 1996; Craig, 2008). Research on CT-fibres has traced their pathways through the thalamus to brain regions involved in emotion and social processing, including the insula, dorsal anterior cingulate cortex, and orbitofrontal cortex (Björnsdotter et al., 2010; Case et al., 2016; Craig, 2009; Gordon et al., 2013; McGlone et al., 2012; Olausson et al., 2002; Voos et al., 2013). The superior temporal cortex, known for processing social cues (Schirmer, 2018), also contributes to touch perception (Ackerley et al., 2012; Bennett et al., 2014; Kaiser et al., 2016). These pathways suggest that CT-optimal touch engages affective and reward-related neural circuits. Functional magnetic resonance imaging (fMRI) has been the primary method for investigating CT-optimal touch, showing distinct neural responses based on touch location and speed (Gordon et al., 2013; Björnsdotter et al., 2010). However, because fMRI relies on indirect blood oxygenation level-dependent (BOLD) signals, it lacks precision in measuring real-time neural activity. In contrast, electroencephalography (EEG), with its high temporal resolution, directly captures neuronal activity and offers a valuable complement to fMRI.

Research linking EEG activity to the sense of touch remains limited, but suggests that different types of touch elicit distinct neural responses. Maulsby (1971) reported that pleasant skin-to-skin stroking in an infant increased theta activity compared to non-pleasant touch. Similarly, Aβ- discriminative touch has been associated with enhanced theta activity and decreased alpha activity, correlating with perceived stimulus intensity (Michail et al., 2016). In the context of CT-optimal touch, Ackerley et al. (2013) observed a frontal ultra-late potential, starting at 1.4 seconds and lasted until 3.1 seconds, while the brush touched the skin at 0.25 seconds, with frontal theta and beta synchronisation (increase in power), and alpha desynchronisation (decrease in power). Conversely, tactile stimulation using fabrics has also been associated with alpha and beta suppression (less alpha and beta) over somatosensory areas, suggesting their involvement in sensory processing and hedonic responses (Singh et al., 2014). Similarly, von Mohr et al. (2018b) found that touch, regardless of valence reduced alpha and beta activity, with decreased theta found only for CT-optimal touch. These findings, though mixed, indicate that the neural signature of touch involves complex interactions between theta, beta, and alpha oscillations, modulated by the emotional quality and context of the touch. Despite these insights, the neural correlates of touch in older adults have yet to be examined, and it is unclear whether different types of touch (beyond CT-optimal and non-CT-optimal) evoke distinct neural patterns. For instance, romantic kissing has been associated with increased alpha asymmetry in the frontal lobe (Packheiser et al., 2021), while havening touch, including hugging, has been associated with increased medial central beta activity (Sumich et al., 2022), in the same way as centroparietal beta activity has been observed following spontaneous self-touch to the face (Grunwald et al., 2014).

Additionally, neural responses to touch seem to be influenced by the relationship between the toucher and the recipient. For example, Kraus et al. (2020) found reduced frontal EEG when holding hands with a close individuals compared to a stranger. Neural oscillatory differences are also found during touch with individuals of different emotional closeness in response to painful experiences. For example, during painful thermal stimulation, holding a partner's hand enhances connectivity between the inferior parietal cortex and dorsomedial prefrontal cortex compared to holding a rubber ball, suggesting that interpersonal touch may alleviate pain through interaction between cognitive and emotion regulation networks (Korisky et al., 2020). Similarly, when individuals face a threat, holding a partner's hand reduces activity in threat-related brain regions (e.g., anterior cingulate gyrus, right dorsolateral prefrontal cortex, caudate) compared to holding a stranger's hand or no hand at all (Coan et al., 2006). However, age-related declines in tactile sensitivity and changes in brain structure may change the way in which touch is perceived (Gillmeister et al., 2017; Kalisch et al., 2009).

Both real and vicarious pain activate similar brain regions, notably the anterior cingulate cortex, a key area involved in pain perception (Morrison et al., 2004; Singer et al., 2004). Likewise, both real and vicarious non-painful stimulation activate the primary somatosensory cortex, including gentle hand pressure (Schaefer et al., 2012), arm stroking (McCabe et al., 2008), and other forms of stimulation (Ebisch et al., 2008; Keysers et al., 2004; Lamm et al., 2015; Masson et al., 2018; McCabe et al., 2008; Peled-Avron et al., 2016; Schaefer et al., 2012). In the context of vicarious touch, emotional stimuli, both visual and auditory, enhance the late positive potential (LPP), a neural marker associated with socio-affective processing, compared to neutral stimuli (Hajcak et al., 2009; Olofsson et al., 2008; Schupp et al., 2000). Close-ups of touch produce greater LPP than close-ups of the same body areas without touch (Peled-Avron & Shamay-Tsoory, 2017). Full-body interaction images are associated with reduced alpha and beta power during touch processing, suggesting activation of sensorimotor areas (Schirmer & McGlone, 2019). However, these findings are context-dependent. Schirmer and McGlone (2019) found that touch images, compared to no-touch images, were associated with higher alpha and beta-power, likely due to the broader context provided by full-body representations rather than isolated touch (Peled-Avron et al., 2016). It remains unclear whether similar neural patterns would emerge in response to full-body videos. Moreover, the neural correlates of different types of vicarious touch, especially in older adults, have yet to be explored.

Thesis Overview

Interpersonal touch is generally pleasant and comforting, promoting health and well-being (Debrot et al., 2013; Hertenstein et al., 2006), while also helping to regulate stress (Candia-Rivera et al., 2024; Ditzen & Heinrichs, 2014). However, much of the existing research has focused on single health systems, overlooking broader multi-system associations. Older adults tend to find touch more pleasant than younger individuals (Sehlstedt et al., 2016) and describe it in more emotional language (Guest et al., 2014), yet they receive less touch (Upenieks & Schafer, 2022). Absence of touch can influence how it is perceived (Heatley Tejada et al., 2020; Sailer & Ackerley, 2019), but there is little research on the relationship between touch and health outcomes in older adults. Differences in touch perception based on emotional closeness (Coan et al., 2006; Floyd et al., 2018; Kreuder et al., 2017; Morriss et al., 2019) and age-related changes in social networks (Donovan et al., 2017; Seeman et al., 1993) suggest that older adults may exhibit unique health outcomes depending on the emotional closeness of the person providing the touch. This research addresses existing gaps by examining the relationship between touch frequency and multi-system health in older adults using the National, Social Life, Health, and Aging Project (NSHAP), a large nationally representative dataset of older adults in the United States. Furthermore, this research explores the association between touch frequency with romantic partners compared to other close individuals and physiological health outcomes, using both cross-sectional and longitudinal methods.

Additionally, this thesis expands its scope to investigate the concept of vicarious touch, which refers to the perception of touch through visual or imagined experiences rather than direct physical contact (Haans & IJsselsteijn, 2009). Vicarious touch is increasingly recognised for its capacity to engage the similar neural pathways and hedonic properties as direct touch (Björnsdotter & Olausson, 2011; Blakemore et al., 2005; Bufalari et al., 2007). Additionally, research has demonstrated that vicarious touch can elicit similar stress-reducing effects, suggesting that the benefits of touch might extend beyond physical interaction (Kirsch et al., 2024). However, existing findings have neglected older adults, a population who may benefit most from such touch interventions, but may also have shown reduced effectiveness of vicarious touch due to reduced tactile sensitivity and empathy-related responses (Gillmeister et al., 2017; Kalisch et al., 2009).

Furthermore, existing studies have predominantly focused on CT-optimal touch representations, while full-body vicarious touch interactions, such as hugs, activate both sensorimotor ad socio-elements, but its processing strongly influenced by emotional context (Schirmer & McGlone, 2019). However, such findings are based on static images of touch, while dynamic videos of vicarious hugs have not been investigated. Moreover, although vicarious touch is associated with reduced perceived stress and increased calmness (Kirsch et al., 2024), the physiological associations of vicarious touch, especially in response to stressful tasks is less well understood. Thus, this research investigates the association between vicarious hug videos and associated physiological responses, whilst viewing the stimuli, but also during a stressor, and during post-stress recovery. Specifically, this research investigates whether there are differences in physiological responses to vicarious hugs that differ in perspective and duration, given that first-person perspectives rather than third-person perspectives activate somatosensory cortex more strongly (Saxe et al., 2006), but also that longer hugs are more pleasant than shorter ones (Dueren et al., 2021).

Finally, this research will investigate longitudinal characteristics of touch in an older sample, and the associated response to a laboratory psychological stressor associated with frequency of touch reported over four months. Additionally, neural responses, using EEG, and cardiovascular responses, using electrocardiogram (ECG) measuring HR and HRV, will discern whether perceptions of different types of touches (CT-optimal stroking, hugging, and handshakes) with individuals of varying emotional closeness (close individuals, strangers, and vicariously observed) will produce different neural oscillations in a sample of older adults.

Specifically, Chapter 2 analyses cross-sectional data from the NSHAP to examine how touch frequency relates to allostatic load, a measure of multisystem stress, at a single time point. It compares the health outcomes of touch with romantic partners versus other close individuals. Chapter 3 builds on these findings by investigating the longitudinal relationship between touch frequency and allostatic load five years later, using the NSHAP. Thus, this chapter focuses on whether the health benefits of touch persist. Similar to Chapter 2, this chapter explores whether romantic partner touch offers greater long-term benefits in stress regulation compared to other relationships. Chapter 4 shifts to vicarious touch, examining how vicarious hugs can influence heart rate, heart rate variability, galvanic skin response, pupil dilation, and facial expressions. This chapter investigates vicarious hug perspectives (first-person, third-person, and neutral) and durations (10 seconds and 30 seconds) on physiological markers, during video viewing, during a stressful task, and in post-stress recovery. Finally, Chapter 5 uses a four-month longitudinal survey and a laboratory-based stressful task to assess the relationship between touch frequency and acute stress in older adults. Furthermore, Chapter 5 uses neural (EEG) and cardiovascular (ECG) responses to different touch types (CT-optimal stroking, hugging, and handshakes) with individuals of varying emotional closeness (a close individual, a stranger, and vicarious observation), directly comparing responses in older adults.

The findings of this thesis have several important implications. First, by examining whether the health-promoting and stress-buffering effects of touch observed in younger adults also apply to older adults, this research contributes to a more nuanced understanding of how touch influences well-being across the lifespan. This is especially relevant given the age-related changes in social networks and potential reductions in touch among older individuals. If the benefits of touch are confirmed in older adults, it may support interventions promoting touch to improve health outcomes in this population. Second, the use of large-scale secondary data allows for more generalizable conclusions about touch frequency and its multi-system associations, providing evidence that extends beyond smaller, more controlled studies. The exploration of emotional closeness adds depth by suggesting that the health impacts of touch may differ depending on the relationship between the individuals involved, with potential implications for social and healthcare practices that prioritise interpersonal support.

Third, the investigation of vicarious touch and its potential to influence physiological outcomes expands the current understanding of how indirect forms of touch, such as watching hugs, can reduce stress. The findings could have practical applications for populations that may receive less direct touch, such as isolated older adults, highlighting new avenues for therapeutic interventions. Furthermore, insights into how perspective and duration affect these responses could inform more personalised approaches to vicarious touch based therapies and stress management, particularly in older adults. Finally, by comparing the neural and cardiovascular correlates of different types of touch (e.g., stroking, hugging, handshakes) with various individuals, including vicarious touch, this research breaks new ground in understanding the underlying neural mechanisms, and heart rate and heart rate variability that differentiate how various forms of touch are processed in older adults.

2. Interpersonal Touch and the Importance of Romantic Partners for Older Adults' Neuroendocrine Health

Introduction

Evidence suggests that close social relationships are associated with lower rates of morbidity and mortality (Holt-Lunstad et al., 2010; see Wang et al., 2023 for review), but the mechanisms underlying these associations and the specific elements of social relationships involved are not fully understood (Uchino, 2006). Notably, close personal relationships offer significant benefits in promoting health, particularly among older individuals. Theoretical perspectives emphasise the importance of emotional closeness (Antonucci et al., 2014), with a hierarchy of associations where spousal and family members provide the highest levels of support.

The physical act of touching serves as a means to indicate social proximity, surpassing the mere presence of others, and plays a role in alleviating distress and promoting a heightened sense of safety (Mikulincer et al., 2003 ; Eckstein et al., 2020). Consequently, research on reductions in physical contact, for example that resulting from social distancing measures implemented during the COVID-19 pandemic (Armitage & Nellums, 2020; Schneider et al., 2023), highlights the potential therapeutic value of non-sexual, affectionate touch in enhancing both physical and emotional wellbeing, particularly for individuals living alone. Von Mohr et al (2021) found that individuals who practiced COVID-19 related social distancing for a longer duration expressed a greater desire for tactile experiences. Evidence suggests that unmet touch needs are associated with adverse outcomes. The absence of touch in adulthood has been linked to symptoms of mood disorders (Floyd., 2014), feelings of loneliness (Heatley Tejada et al., 2020), and a decline in general wellbeing (Debrot et al., 2021).

Complementary research also shows the therapeutic potential of touch for health. In Ditzen et al’s (2007) study, a 10-minute session of physical touch, specifically a neck and shoulder massage between romantic partners prior to a psychosocial stressor, resulted in greater regulation of the female partner’s heart rate and cortisol responses compared to verbal support. Effects were not examined in male partners. Heinrichs et al (2003) propose that social interactions, including emotional support from others, contribute to the regulation of the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS), leading to the suppression of physiological stress systems. Recent research proposes that interpersonal touch stimulates the oxytocinergic system, releasing oxytocin from hypothalamic nuclei to reduce stress (Uvnäs Moberg et al., 2020). It is suggested that physical touch may have a greater dampening effect on the activity of the HPA axis and ANS compared to verbal support (Ditzen et al., 2007). However, previous research has often overlooked the interdependence of physiological systems, and the available evidence primarily stems from laboratory-based intervention studies that focused predominantly on romantic couples.

What do we know about the factors that determine the frequency of interpersonal touch between individuals? Younger individuals prefer closer proximity to others and are more likely to engage in touch compared to their older counterparts (Upenieks & Schafer, 2022), indicating a negative association between age and preferred interpersonal distance. Additionally, emotionally close individuals are more likely to engage in touch, with broader areas of the body being touched and for more reasons (Suvilehto et al., 2015). The power of touch is particularly evident in romantic relationships, where activities such as hand holding between partners have been shown to result in increased brain-to-brain coupling (neural synchrony), and relief from pain as measured using electroencephalogram (EEG) (Goldstein et al., 2018). Moreover, increased touch from a spouse during discussions about stressors has been associated with lower stress levels, higher self-esteem, and greater perceptions of being able to overcome the stressor (Jakubiak & Feeney, 2019). The benefits of physical touch extend beyond romantic relationships. For instance, in healthcare settings, when nurses touch patients, it has been observed to improve sleep, blood pressure, respiratory rate and pain (Papathanassoglou & Mpouzika, 2012). Despite the advantages of touch from different sources, there is a need for direct comparisons examining the specific health benefits of touch received from a romantic partner compared to touch received from other adults.

Given the interrelation of various physiological systems in maintaining internal homeostasis and responding to stressors it is important to explore whether touch from romantic partners has unique or amplified associations compared to touch from other sources. This is particularly relevant in the context of allostasis, which refers to the internal adaptation of the body to maintain physiological stability by matching the internal milieu with environmental stressors (Sterling & Eyer, 1988). Over time, repeated exposure to stressful experiences can increase the body's allostatic load (AL), which represents the cumulative physiological burden resulting from the need for continuous adjustment to maintain allostasis (Seeman et al., 2001). High AL is often associated with poor cognitive and physical functioning (Karlamangla et al., 2002), cardiovascular disease (Seeman et al., 2001) and all-cause mortality (Goldman et al., 2006). AL is constructed by aggregating primary mediators (e.g., the stress hormone cortisol), indicating responses to environmental threats, and secondary mediators (e.g., raised blood pressure) reflecting prolonged biological adjustments often leading to disease (Seeman et al., 2001). The calculation of AL has been a topic of debate, with various approaches employed in the literature, including a count of multiple physiological markers (Seeman et al., 1997), canonical correlation (Karlamangla et al., 2002) and principal component analysis (PCA) (D'Alonzo et al., 2019). Among these approaches

PCA offers the advantage of accounting for the underlying dimensions within the AL construct.

Evidence suggests that greater emotional support from friends and family is associated with lower AL in older age groups (Seeman et al., 2014). While the mechanisms that link emotional support and AL are presently unclear, we hypothesize, that interpersonal touch may play a role. This study will focus on the relationship between frequency of touch and AL, a measure of multisystem dysregulation, in older adults. In addition to age, this study examines if associations vary by whether touch is with romantic partners as compared to other close adults. We hypothesise that (1) more frequent physical touch will be associated with lower AL as compared to less frequent touch, and (2) this relationship will be stronger for frequent touch with romantic partners as compared to other close adults.

Methods

Participants

Data is used from the National Social Life, Health and Aging Project (NSHAP), a longitudinal study of a nationally (U.S.) representative sample of population-based, community-residing older adults. The NSHAP used interviews, biological samples and questionnaires from a randomly selected subset of respondents (O'Muircheartaigh et al., 2009). The survey included an oversampling of black, Hispanic, and oldest age individuals (75-85 years), using a complex, multistage area probability sampling design with post stratification. This analysis uses data from Wave 1 conducted between 2005-2006 with 3,005 individuals, born between 1920 and 1947 (aged 57–85 years: 1,455 men and 1,550 women), achieving an overall response rate of 75.5%.

To the best of our knowledge, the NSHAP is also the only nationally representative study to include items about non-sexual touch between adults. For the analyses reported in this paper, only the base wave respondents (n = 3,005) were utilised. There were 1,419 respondents with no missing data for outcome variables, this was our analytic sample. A comparison of the analytic sample and the non-analytic (n = 1,586) characteristics can be found in Appendix Table A.1. Their average age was 69.35 years (SD = 7.76), 48.98% were women, 74.58% were white and 66.53% had a romantic partner.

Touch Frequency

Two questions from the wave 1 questionnaire measured touch frequency with romantic partners and other close adults. The questions used were “In the last 12 months, how often have you engaged in the following activities: hugging, kissing, caressing, or other close physical contact with your partner?” and “In the last 12 months, how often have you engaged in the following activities: hugging, holding, or other close physical contact with another adult?”. The NSHAP defined other adults as family members, neighbours and friends. Each question was treated as an independent exposure variable representing touch frequency with different individuals. Participants answered using a 7-point scale from 0 (never) to 6 (several times a week).

Allostatic Load (AL)

Principal components analysis (PCA) of AL was used to measure multi-system dysregulation. The NSHAP dataset includes eight AL biomarkers (see to Table 2.1). The measures encompassed neuroendocrine system functioning (dehydroepiandrosterone (DHEA)); immune system functioning (c-reactive protein (CRP)); metabolic system functioning (glycosylated haemoglobin (HbA1c)); cardiovascular functioning (systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate); and anthropometric functioning (body mass index (BMI) and waist circumference). Availability and matching as closely as possible those markers employed in prior research determined the combination of markers used to construct AL (refer to Table 2.1). CRP was log transformed and DHEA was inverse transformed to better approximate a normal distribution based on data inspection.

Table 2.1. *Individual components of the AL index in the NSHAP*

Biomarkers to be used in this study (outcomes)	**Application**	**Method**
C-reactive protein (CRP, mg/l*)*	Inflammation due to injury or infection, acute or chronic response to stress	Minimum 250UL of blood were collected from the middle finger on the non-dominant hand, or if not available, the middle finger on the dominant hand. CRP values were assayed using an enzyme-linked immunosorbent assay protocol (McDade et al., 2004). The Roche Unimate immunoassay and Cobas Inegra Analyzer were used for HbA1c values.
Glycosylated Haemoglobin (HbA1c, mmol/mol*)*	Blood sugar regulation	
Dehydroepiandrosterone (DHEA, µmol/l*)*	Adrenal gland steroid	2 mL of saliva provided using a small chewable sponge. Results were based on an average of two laboratory tests. Identical enzyme immunoassays were used for DHEA values.
Systolic blood pressure (sBP. mmHg*)*	Indices of cardiovascular activity	The mean of two digital blood pressure monitor readings. A one-minute period was left between the first and second reading
Diastolic blood pressure (dBP, mmHg*)*		
*Pulse (*beats per minute)		
Body Mass Index (BMI, kg/m^2*)*	Indices of anthropometric functioning	Scales switched to pounds, and measuring tape for height (recorded to the nearest half inch)
Waist Circumference (inches)		Measuring tape around the narrowest part of the torso just above the navel

Covariates

Sexual Touch. Sexual touch was a categorical variable with three groups: (1) no sex in the last 12 months, (2) infrequent sexual touch, and (3) frequent sexual touch. These categories were derived based on responses to two questions. The first question was "had sex in the last year?" which had responses of yes or no. For respondents who answered yes, a second question was used "when you had sex with your partner in the last 12 months, how often did your activities include kissing, hugging, caressing, or other ways of sexual touching?" Respondents provided ratings on a 5-point scale from 1 (never) to 5 (always). Individuals who reported always sharing sexual touching during their sexual encounters were categorised as having 'frequent' sexual touch, while all other groups were combined and categorised as having 'infrequent' sexual touch.

Alcohol Intake. Three variables measured alcohol intake: "Have you ever drunk alcohol?", "Do you drink alcohol?", and "How many days per week do you drink?" This was a categorical variables with three groups: (1) regular drinkers (respondents who drink alcohol at least one day per week); (2) non-regular drinkers (respondents who drink alcohol less than one day a week), and (3) never drank alcohol.

Household Composition. Number of co-residents was as a categorical variable with three groups including (1) lives alone, (2) lives with one other person, and (3) lives with two or more persons.

Romantic Partner. The romantic partner variable was treated as a binary variable for those who do have a romantic partner (married, living with a partner, or has a romantic, intimate, or sexual partner) and those who do not (separated, divorced, widowed, never married, and does not have a romantic, intimate or sexual partner).

Sociodemographic characteristics

Sex and ethnicity were measured as binary variables (men and women; white and non-white (black and Hispanic respondents)). Respondent's age was categorised into three groups: (1) 57-64, (2) 65-74, and (3) 75-85 years. Social economic position (SEP) combined two variables; total household assets (property, cars, businesses, financial assets etc.) and educational attainment. Educational attainment was measured as a categorical variable with four groups, including (1) less than high school, (2) high school degree or equivalent, (3) some college or associate degree, and (4) bachelor's degree or higher. Total household assets was also a categorical variable with four groups: (1) $0-49,999, (2) $50,000-99,999, (3) $100,000-499,999, and (4) $500,000 or more.

Statistical analyses

PCA empirically determined the underlying dimensions associated with the biomarkers commonly used to construct AL. While the original AL model used a single score, research that is more recent has suggested that a multiple-component model might explain more of the variance in AL (McCaffery et al., 2012). Analysing the eigenvalues, scree plots, and components loadings for each of the eight biomarkers provided the basis for deciding how many underlying components to retain. The identified components were the outcome variables, representing metabolic, cardiovascular, and neuroendocrine health. To describe respondent characteristics of touch frequency by demographic characteristics and covariates, we used cross-tabulations and Chi-Square Test of Independence with Benjamini-Hochberg correction for multiple comparisons.

Following recommendation (O'Muircheartaigh et al., 2009), the original data were weighted using a probability weight, accounting also for the multi-stage sampling design, and adjusted for nonresponse. Multiple imputation using chained equations (MICE) with 20 imputations (White et al., 2011) addressed missing data (assumed to be missing at random), with the intention of avoiding loss of data and statistical power. We imputed all variables except for the outcome variables. Further analyses used the multiple imputed data based on 1,419 cases. Imputation models included NSHAP survey weights.

Next, linear regression models adjusted for sociodemographic characteristics (age, sex, ethnicity and SEP) were used to examine the association between the three outcome component loads in separate models (metabolic, cardiovascular and neuroendocrine) with each covariate. Last, multiple regression tested the association between touch frequency separately from romantic partners and other close adults and each component load following stepwise adjustment for a series of covariates; household composition, romantic partner (only for the touch frequency with other close adults models), sexual touch and alcohol intake. We conducted the statistical analyses using STATA 14.1 (StataCorp. 2015. Stata Statistical Software: Release 14.1. College Station, TX: StataCorp LP).

Results

Participant characteristics

Table 2.2 shows the relationship between touch frequency (from partners and other adults), sociodemographic variables and covariates in NSHAP wave 1. To account for multiple comparisons, the Benjamini-Hochberg correction was applied to the p-values obtained from chi-square tests. The results reported remained statistically significant after adjustment. More frequent touch with romantic partners was reported by white respondents ($X^2(3) = 33.63$, $p < .001$), the most educated ($X^2(9) = 27.55$, $p = 0.001$), those who shared more sexual touch ($X^2(6) = 109.58$, $p < .001$) and respondents who reported infrequent touch with other close adults ($X^2(9) = 59.46$, $p < .001$). More frequent touch with other close adults was reported by women ($X^2(3) = 43.85$, $p < .001$), white respondents ($X^2(3) = 10.18$, $p = 0.017$), and those with some college or associate degree ($X^2(9) = 26.82$, $p = 0.001$).

Table 2.2. *Descriptive statistics of touch frequency by demographic characteristics and covariates in Wave 1 (2005-06) of the NSHAP*

Variables	**N=**	Partner Touch Frequency **(%)**				**N=**	Touch with Others Frequency **(%)**			
		Yearly or Less	Monthly	Weekly	>Weekly		Yearly or Less	Monthly	Weekly	>Weekly
Sex	**878**					**878**				
Women [a]		46.48	30.00	38.55	36.09		39.80	53.33	58.78	59.54
Ethnicity	**859**					**1,278**				
White [b]		64.71	60.42	72.50	84.62		74.49	84.38	77.01	71.09
Age (y)	**878**					**1,309**				
57-64		28.99	46.00	34.94	40.09		32.50	32.73	32.26	34.73
65-74		37.68	36.00	42.17	38.61		37.81	40.00	36.92	40.08
75-85		33.33	18.00	22.89	21.30		29.68	27.27	30.82	25.19
Educational Attainment	**878**					**1,309**				
<High School		30.43	28.00	18.07	13.76		22.06	15.15	18.28	24.81
High School Degree or Equivalent		31.88	28.00	31.33	26.04		31.34	21.21	24.01	23.28
Some College or Associate Degree		26.09	24.00	22.89	31.80		26.87	30.91	32.62	28.24
Bachelor's Degree or Higher		11.59	20.00	27.71	28.40		19.73	32.73	25.09	23.66
Total Household Assets ($)	**628**					**925**				
0-49,999		15.69	15.38	13.56	10.44		19.86	15.08	14.43	26.20
50,000-99,999		11.76	17.95	6.78	8.98		12.44	9.52	12.37	11.76

100,000-499,999		45.10	41.03	40.68	40.50		39.00	43.65	41.24	36.36
500k or higher		27.45	25.64	38.98	40.08		28.71	31.75	31.96	25.67
Number of co-residents	**877**					**1,306**				
Lives alone		4.35	12.00	7.23	5.63		24.75	29.70	28.06	27.20
Lives with one other person		73.91	60.00	69.88	75.26		54.98	51.52	55.40	48.28
Lives with two or more persons		21.74	28.00	22.89	19.11		20.27	18.79	16.55	24.52
Romantic Partner						**1,309**				
Yes [c]							68.82	66.06	67.03	64.50
Frequency of Sexual Touch	**842**					**1,265**				
No Sex		70.15	29.79	41.56	23.81		51.56	46.25	48.18	51.78
Infrequent Sexual Touch		16.42	34.04	22.08	11.06		11.07	13.12	7.66	9.88
Frequent Sexual Touch		13.43	36.17	36.36	65.13		37.37	40.62	44.16	38.34
Alcohol Intake	**646**					**952**				
Never Drank		22.00	25.71	10.61	13.13		21.38	12.03	18.06	23.63
Non-Regular Drinker		26.00	17.14	34.85	23.84		27.55	20.30	25.93	23.08
Regular Drinker		52.00	57.14	54.55	63.03		51.07	67.67	56.02	53.30
Touch with others	**874**									
Yearly or Less		78.26	70.83	42.17	43.03					
Monthly		5.80	20.83	18.07	11.72					
Weekly		8.70	8.33	25.30	23.00					
>Weekly		7.25	0.00	14.46	22.26					

Note. These descriptive statistics were produced prior to the imputation of missing values for all variables except the biomarkers used as the outcome variables. Descriptive statistics were computed for each comparison separately, resulting in varying sample sizes due to missing data on the exposure variables and covariates.

[a] Compared to men

[b] Compared to non-white respondents

[c] Compared to no romantic partner available

Data reduction: Principle component analysis of biomarkers

PCA with oblique rotation uncovered the number of components among eight AL markers. Three components had eigenvalues greater than 1, a common rule of thumb for determining the number of components to retain (Costello & Osborne., 2005). A scree plot graphically represented this (see Appendix Figure A.1). The component loadings for the total sample range from -0.49 to 0.89 (see Appendix Table A.2). Most strongly correlated with the underlying component for metabolic health were BMI (0.89), waist circumference (0.89), log transformed CRP (0.49), and HbA1c (0.47). Most strongly correlated with the underlying component for cardiovascular health were systolic blood pressure (0.88) and diastolic blood pressure (0.87). Most strongly correlated with the underlying component for neuroendocrine health were pulse (0.82) and DHEA (-0.49).

Relationship of components of AL and covariates

Linear regression models were performed to examine the associations between covariates and each component load, including metabolic, cardiovascular and neuroendocrine health, serving as outcome variables (see Table 2.3). The results revealed significant associations between higher educational attainment, greater total household assets and increased engagement in sexual touch with better metabolic health. Conversely, reduced alcohol intake and an increased household number were associated with worse metabolic health.

Regarding cardiovascular health, a significant association was observed with romantic partner availability. Respondents who reported having a romantic partner exhibited better cardiovascular health compared to those without a romantic partner. Furthermore, better neuroendocrine health was significantly associated with greater total household assets, and increased engagement in sexual touch. Conversely, worse neuroendocrine health was significantly associated with living alone.

Table 2.3. *Associations between covariates and metabolic, cardiovascular and neuroendocrine health, adjusted for age, sex and ethnicity (N = 1,419)*

Covariates	**Outcome Variables**					
	Metabolic Health		Cardiovascular Health		Neuroendocrine Health	
	Estimates	***95% CI***	***Estimates***	***95% CI***	***Estimates***	***95% CI***
Educational Attainment [a]						
< High School Degree	0.08	-0.09 – 0.25	-0.05	-0.20 – 0.09	0.12	-0.13 – 0.36
High School Degree or Equivalent	0.05	-0.09 – 0.19	0.00	-0.13 – 0.13	0.04	-0.16 – 0.24
Bachelor's Degree or Higher	-0.22**	-0.36 – -0.07	-0.02	-0.20 – 0.16	-0.19	-0.42 – 0.03
Total Household Assets [b]						
$0-$49,999	0.09	-0.18 – 0.36	0.06	-0.15 – 0.27	0.30*	0.08 – 0.53

$50,000-$99,999	0.16	-0.12 – 0.44	0.03	-0.29 – 0.35	0.22	-0.09 – 0.53
$500k or higher	-0.25**	-0.43 – -0.08	-0.02	-0.20 – 0.16	-0.21*	-0.41 – -0.00
Sexual Touch [c]						
Infrequent Sexual Touch	-0.15	-0.40 – 0.11	0.07	-0.15 – 0.30	-0.07	-0.31 – 0.18
Frequent Sexual Touch	-0.30**	-0.46 – -0.14	-0.04	-0.21 – 0.13	-0.23**	-0.39 – -0.08
Alcohol Intake [d]						
Non-Regular Drinkers	0.30**	0.14 – 0.47	-0.01	-0.20 – 0.18	-0.02	-0.22 – 0.18
Never Drank Alcohol	0.35**	0.15 – 0.56	-0.08	-0.28 – 0.12	0.04	-0.17 – 0.26
Household Composition [e]						
Lives Alone	0.00	-0.20 – 0.20	0.15	-0.01 – 0.32	0.22*	0.03 – 0.42
Lives with Two or More Persons	0.25**	0.07 – 0.43	-0.01	-0.19 – 0.17	0.02	-0.16 – 0.21
Romantic Partner [f]						
No	0.14	-0.01 – 0.30	0.22**	0.07 – 0.37	0.15	-0.01 – 0.30

Note. Reference categories were chosen based on largest group.

[a] Educational Attainment reference category is ‘Some College or Associate Degree’.

[b] Total Household Assets reference category is ‘$100,000 - $499,999’.

[c] Sexual Touch reference category is ‘No Sex in the Last 12 Months’.

[d] Alcohol Intake reference category is ‘Regular Drinkers’.

[e] Household Composition reference category is ‘Lives with One Other Person’.

[f] Romantic Partner reference category is ‘Yes’.

$^{*}p < .05$. $^{**}p < .01$.

Relationship of components of AL and touch

Multiple regression by stepwise adjustment models built on each base model (adjusted for sociodemographic characteristics: age, sex, ethnicity and SEP), with covariates added incrementally. Regarding the relationship between touch frequency and metabolic health, no significant associations were found (see Table 2.4 and Appendix Figure A.2). Similarly, no significant association was found between touch frequency and cardiovascular health (see Table 2.4 and Appendix Figure A.3). However, in the case of neuroendocrine health, analyses revealed a significant relationship with romantic partner touch frequency. The findings indicated that a one-unit increase in touch frequency with romantic partners resulted in a 0.13 standard deviation increase in the neuroendocrine health component loading (see Table 2.4 and Figure 1). This association remained robust to adjustment with all covariates examined, with only minimal changes to the regression coefficient occurring beyond the second decimal place. On the other hand, the relationship between touch frequency with close others and neuroendocrine health was found to be non-significant. The general trend suggested better neuroendocrine health as the frequency of touch with close other adults decreased (see Figure 2.1).

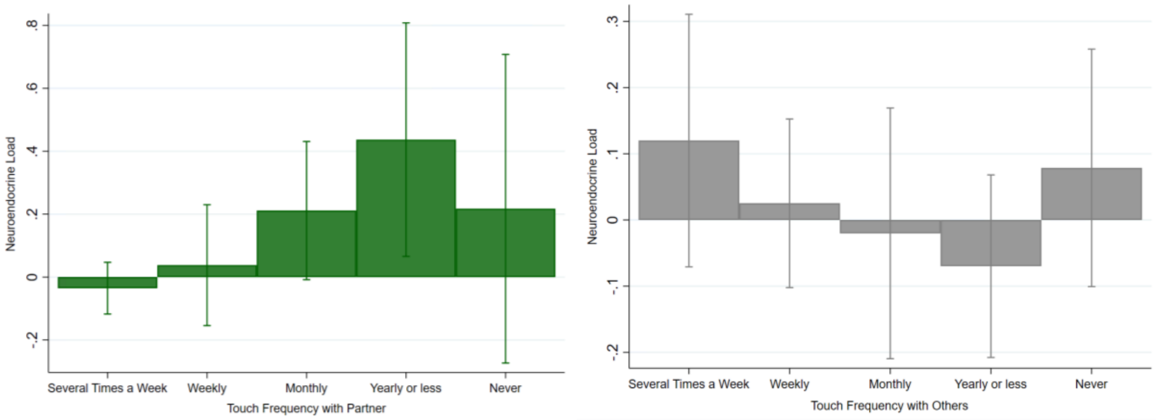
Table 2.4. *The relationship between touch frequency from partners or other close adults and each component load (N = 1,419)*

	Covariates sequentially added to base models	Partner touch frequency	Close other adult touch frequency
Metabolic Health			
Model 1	Base model	β = 0.01, p = 0.849	β = 0.01, p = 0.508
Model 1 +	Household composition (model 2)	β = 0.01, p = 0.650	β = 0.01, p = 0.531
Model 2 +	Romantic partner availability (model 3)		β = 0.01, p = 0.553
Model 3 +	Sexual touch (model 4)	β = -0.02, p = 0.648	β = 0.01, p = 0.709
Model 4 +	Alcohol intake (model 5)	β = -0.02, p = 0.645	β = 0.00, p = 0.932
Cardiovascular Health			
Model 1	Base model	β = -0.06, p = 0.144	β = 0.02, p = 0.337
Model 1 +	Household composition (model 2)	β = -0.07, p = 0.117	β = 0.02, p = 0.330
Model 2 +	Romantic partner availability (model 3)		β = 0.02, p = 0.344
Model 3 +	Sexual touch (model 4)	β = -0.08, p = 0.097	β = 0.02, p = 0.305

Model 4 +	Alcohol intake (model 5)	β = -0.08, p = 0.097	β = 0.02, p = 0.266
Neuroendocrine Health			
Model 1	Base model	**β = 0.13, p = 0.002**	β = -0.01, p = 0.585
Model 1 +	Household composition (model 2)	**β = 0.13, p = 0.002**	β = -0.01, p = 0.594
Model 2 +	Romantic partner availability (model 3)		β = -0.01, p = 0.598
Model 3 +	Sexual touch (model 4)	**β = 0.13, p = 0.004**	β = -0.02, p = 0.506
Model 4 +	Alcohol intake (model 5)	**β = 0.13, p = 0.004**	β = -0.02, p = 0.541

Note. The base model estimates the relationship between each outcome load (metabolic, cardiovascular and neuroendocrine) and touch frequency, separately for partners and other close adults, and are adjusted for sociodemographic characteristics (age, sex, ethnicity and SEP).

Figure 2.1. *Mean neuroendocrine health by decreasing touch frequency by partner (left) and others (right)*



Note. More positive neuroendocrine load scores indicate worse neuroendocrine health. Lines represent 95% confidence intervals.

Discussion

The present study aimed to improve the understanding of the associations of touch absence in the ageing population. This study explored the relationship between frequency of interpersonal touch and components of AL in older adults, with the additional objective of examining whether touch exchanged with romantic partners differed in its associations from touch shared with other close individuals. We hypothesised that respondents who reported more frequent physical touch would have lower AL compared to those with less frequent touch, and that this relationship would be more robust for touch with romantic partners as compared to other close adults. Our findings suggest that the AL construct is not homogeneous. Our findings also provide the first evidence that touch frequency with romantic partners is associated with neuroendocrine health in older adults. Specifically, individuals who reported sharing touch with their romantic partners more frequently exhibited better neuroendocrine health compared to those who shared touch infrequently with partners. No benefits were observed for respondents who reported frequent touch with other close adults. Our findings align with prior studies indicating that physical touch may have protective effects against various stress-related outcomes in laboratory settings, including lower cortisol levels in humans (Ditzen et al., 2007).

Moreover, our results support the notion that the benefits of touch are more pronounced in romantic partnerships (Coan et al., 2006). This is consistent with previous research supporting the enduring advantages of touch with romantic partners in mitigating stress and improving physiological well-being. These studies have shown that even brief physical contact with romantic partners can lead to immediate and prolonged benefits, such as reduced blood pressure and heart rate reactivity (Grewen et al., 2003; Triscoli et al., 2017). While previous research has established that touch with romantic partners can reduce acute stress and improve health, our study makes a unique contribution by uncovering the potential of frequent touch with romantic partners specifically for cultivating neuroendocrine health in older adults. This interplay between partner touch, neuroendocrine regulation, and stress management contributes to a deeper understanding of the therapeutic potential of touch in older adult populations.

This study used eight AL markers; CRP, HbA1C, DHEA, sBP, dBP, pulse, BMI, and waist circumference. As previously mentioned, high AL is often associated with poor cognitive and physical functioning (Karlamangla et al., 2002), cardiovascular disease (Seeman et al., 2001) and all-cause mortality (Goldman et al., 2006). There is currently no consensus on the number and range of biomarkers to measure AL effectively. Mauss et al (2015) found in a systematic review that 39 different biomarkers, ranging between six and 17 measures per study had been used. Although evidence suggests that diversity of biomarkers used to measure AL is not problematic (Juster et al., 2010). A recent meta-analysis (McCrory et al., 2023) identified a panel of five specific AL markers that consistently exhibit associations with health and mortality. These markers, namely CRP, heart rate, high density lipoprotein cholesterol (HDL), waist-to hip-ratio, and HbA1c, have been recommend by the authors for inclusion in future studies to facilitate comparisons of cumulative physiological burden across various socio-demographic groups and age ranges. Although our study encompasses four out of these five core markers, it is worth noting that the results might have differed if HDL had been included. The inclusion of HDL in future investigations would provide a more complete assessment of touch frequency and its implications for health outcomes.

We used PCA to investigate whether the biological markers measured in the NSHAP can be operationalised to assess AL and whether they function as a single construct or multiple systems. PCA identified that AL loads onto three individual system components (metabolic, cardiovascular and neuroendocrine health), as seen in previous literature (McCaffery et al., 2012). In our analyses, we classified the factor showing high loadings for DHEA and pulse as ‘neuroendocrine’. DHEAS is produced by the adrenal glands (Suzuki et al., 1991), while pulse is an indicator of vagal function (Porges, 2007). DHEA and its metabolites have immune-enhancing properties (Suzuki et al., 1991), which are important for the stress response system and include anti-inflammatory and anti-glucocorticoid effects. DHEA also stimulates the secretion of catecholamine’s, playing a key role in regulating the HPA axis (Maninger et al., 2009). DHEAS, the blood-borne form of DHEA, is widely recognised as one of the key neuroendocrine markers for a reasonably constructed AL.

Ideally, we would have used heart rate variability (HRV) to assess autonomic nervous system regulation. HRV provides insights into the activity of both the sympathetic and parasympathetic nervous systems, which can be influenced by the HPA axis (Bigger et al., 1993). However, HRV was not available in the NSHAP dataset. In this sample, pulse and

DHEA were most strongly correlated to the neuroendocrine load component, as such; pulse may be acting as a substitute of HRV, and representing autonomic balance (Thayer & Brosschot., 2005). Future studies should consider incorporating direct HRV measurements to obtain a more comprehensive understanding of autonomic nervous system regulation in relation to the HPA axis.

Our results indicate that touch with partners has greater salience to neuroendocrine health than touch with others. Romantic partners often develop a stronger emotional connection, which could lead to heightened positive emotional experiences during physical touch. Positive emotional experiences, including touch have been shown to stimulate the release of hormones, such as oxytocin, that have positive effects on neuroendocrine health (Holt-Lunstad et al., 2008; Uvnäs Moberg et al., 2020). Secondly, touch between romantic partners tends to be more intimate and varied compared to touch with other close adults. For instance, touch between romantic partners tends to be more frequent (Heslin & Alper., 1983; Suvilehto et al., 2019; Sorokowska et al., 2021) and sustained compared to touch with other close adults, and may involve more kissing, hugging, and sexual touch, which can elicit a broader range of physical sensations and emotions. Duration of and variety in touch experiences may lead to more positive emotions and greater and more consistent stimulation of hormones that promote neuroendocrine health (Light et al., 2005). Future studies could substantiate this speculation by measuring hormonal secretion from romantic partners touch as compared to touch with other adults directly.

The association of romantic partner touch and neuroendocrine health was robust to the adjustment of a wide range of covariates. Of the covariates examined, we saw that respondents with a romantic partner exhibited better cardiovascular health compared to those without a romantic partner. This suggests that the mere presence of a romantic partner has protective effects on cardiovascular health. Covariate associations also revealed that worse metabolic health was also associated with increased household size, whilst living alone was associated with worse neuroendocrine health, in line with existing literature showing that household composition can affect health (Henning-Smith et al., 2016). Improved metabolic and neuroendocrine health were associated with greater total household assets and frequent affective touch during sexual intercourse. Previous studies have demonstrated that physical affection and sexual activity are linked to reduced same-day negative moods and stress (Burleson et al., 2007). This may be attributed to the enhanced release of oxytocin associated with both touch and sexual activity (Carmichael et al., 1987; Lund et al., 2002). Consequently, it would be valuable for future studies to carefully examine and isolate the effects of sexual and non-sexual touch frequency.

In this study, no effects emerged of touch frequency with close adults on metabolic, cardiovascular and neuroendocrine health. There were also no effects of touch frequency with romantic partners on metabolic and cardiovascular health. These results contradict existing literature that suggests a positive association between touch-based interventions and cardiovascular health and stress reduction (Hou et al., 2010), which suggests that touch may indirectly improve metabolic health. The lack of association found in our study may be attributed to the limitations of the NSHAP touch questions, which did not capture the type or context of the touch reported by respondents. For example, kissing on the lips and hugging (Gulledge et al., 2003) are rated as more expressive of love than backrubs and massages. As the NSHAP touch questions did not encompass these distinctions, they should be investigated in future studies on touch as a stress co-regulatory mechanism in older adults. Stress can also be harmful in romantic relationships, and heightened metabolic and/or cardiovascular stress may impair a romantic relationship, which could make touch between partners less pleasant (Randall & Bodenmann, 2009). Future research should therefore also investigate the impact of relationship quality on the association between touch and metabolic and cardiovascular health.

The advantages and limitations of this study require discussion. This is a large study of older men and women, examining several confounders and mediators. Analyses were based on data limited to a subset of participants who had no missing values for all eight biomarkers used as outcome variables. Although there were minor variations between the analytic sample and the non-analytic sample across different sociodemographic characteristics and covariates, the differences were generally not substantial (refer to Appendix Table A.1). Secondly, analyses were cross-sectional, which limits interpretation of the direction of the relationship. One could argue that healthy individuals with a better neuroendocrine health have more opportunities to share touch with their romantic partners, for example. While, several theoretical arguments suggest that touch frequency can benefit chronic stress in the direction of causality we suggest (Field., 2010; Holt-Lunstad et al., 2015), future research would benefit from examining the bidirectional links between touch frequency with romantic partners and neuroendocrine health over time. Additionally, social desirability bias may have influenced subjective self-reported measures of physical touch. While NSHAP is the only nationally representative dataset of older adults to include questions about non-sexual touch from different close resources, the questions and response choices are vague and retrospective. Further research would benefit from direct investigation of the duration, quality, and types of touch (sexual or non-sexual, goal-directed or spontaneous) and their effects on AL. Similarly, future studies should explore how touch with strangers or less close acquaintances affects AL.

In summary, our study has revealed for the first time associations indicating that physical touch plays a role in the health-promoting effects of romantic relationships among older adults, surpassing relationships with other close adults. Our findings suggest that physical touch between romantic partners is linked to a reduction in the burden on the neuroendocrine system, encompassing hormonal and physiological stress responses. Specifically, it suggests that such touch is associated with a decrease in the release of stress-related hormones like DHEA. These observed benefits could potentially be mediated by central nervous neuroendocrine systems (e.g., oxytocin and opioids), which help dampen the stress response of the HPA axis and ANS during stressful situations (Heinrichs et al., 2003). Considering the expected significant increase in the global older adult population in the coming decades, these findings underscore the importance of fostering physical touch within romantic partnerships as a means to support the well-being and health of the growing ageing population.

3. The Longitudinal associations between Romantic Touch and Metabolic and Cardiovascular Health in Older Adults

Introduction

Touch serves as a fundamental aspect of human development, transcending mere tactile sensation to shape our social fabric and well-being (Baumeister & Leary, 2017). Interpersonal touch is usually pleasant and comforting, and has the ability to strengthen connections between individuals, promote overall well-being, and convey emotional and motivational signals (Debrot et al., 2013; Hertenstein et al., 2006). In addition to this wealth of benefits, interpersonal touch has also been found to serve health benefits, particularly in response to stressful conditions, it appears to dampen various stress systems, such as the autonomic nervous system (ANS) (Candia-Rivera et al., 2024; Lindgren et al., 2010) and the hypothalamic-pituitary-adrenal (HPA) axis (Ditzen & Heinrichs, 2014).

Stress may be defined as a threat, real or implied, to the psychological or physiological integrity of an individual (McEwen, 2013).When a threat is detected, brain structures like the amygdala and hypothalamus initiate bodily changes to manage the response to the stressor (McEwen & Akil, 2020). The sympathetic nervous system responds by releasing adrenaline, which increases heart rate and blood circulation, preparing the body for immediate action (Herman et al., 2020). Simultaneously, the HPA axis triggers the release of cortisol and other stress hormones, providing the energy needed to sustain activity in response to the stressor (Herman et al., 2020). The concept of allostasis describes how chronic stressors disrupt the body’s balance, pushing it away from homeostasis (McEwen & Akil, 2020). While the stress response is adaptive and protective, it comes with an energy cost known as allostatic load (McEwen & Akil, 2020). The theory of allostatic load explains how chronic or repeated stress can lead to wear and tear on the body’s regulatory systems, potentially contributing to disease and poor health (McEwen, 1998). This wear and tear can result from repeated exposure to stressors, lack of adaptation to the stress, delayed recovery, or an inadequate stress response requiring compensation from other systems.

Despite the crucial role sensory systems play in detecting and managing stressors (Fast & McGann, 2017), their potential for therapeutic intervention remains underexplored. Interpersonal touch offers a promising approach to improving stress coping through various physiological mechanisms. Touch, such as stroking, hand-holding, or hugging, conveys proximity and positive affiliation, often perceived as signals of safety (Eckstein et al., 2020). These effects are likely mediated by increased secretion of oxytocin, a neuropeptide linked to bonding and stress relief (Kreuder et al., 2019; Sue Carter, 1998; Tang et al., 2020; Uvnäs-Moberg, 1998). Additionally, tactile stimulation is associated with increased vagus nerve activity, leading to reduced physiological responses, including lower HPA and ANS activity, and decreased overall arousal (Ferrell-Torry & Glick, 1993; T. M. Field, 1998).

Different types of touch, such as gentle caressing of the forearm or back of the hand, can alleviate feelings of social exclusion (von Mohr et al., 2017) and loneliness (Heatley Tejada et al., 2020). Additionally, whom the touch is shared with also matters. For instance, touch from waiters can enhance positive affect (Fisher et al., 1976) and lead to higher tips (Stephen & Zweigenhaft, 1986), while in healthcare settings, touch from nurses can improve sleep, blood pressure, respiratory rate and pain (Papathanassoglou & Mpouzika, 2012). However, touch within romantic relationships is particularly impactful, being associated with better long-term psychological well-being (Debrot et al., 2013) and providing support in stressful situations by reducing heart rate, blood pressure (Drescher et al., 1980; Drescher et al., 1985; Grewen et al., 2003; Lynch et al., 1974; Triscoli, Croy, Olausson, et al., 2017), and cortisol production (Ditzen et al., 2007). Unsurprisingly, individuals in romantic relationships engage in more frequent tactile interactions (Beßler et al., 2020; Guerrero, 1997). Although, some research has found no difference in children and adults comparing touch applied by a familiar person or a health professional (Packheiser et al., 2023). Despite the known benefits of various forms of touch, few studies have compared the effects of touch frequency with romantic partners versus other close adults on health outcomes. This comparison is important, as not everyone has a romantic partner, and the absence of touch can be detrimental to health.

During the COVID-19 pandemic, social distancing measures led to a significant reduction in touch, which correlated with increased loneliness, anxiety, depression, and diminished well-being (Heidinger & Richter, 2020; Palgi et al., 2020; Von Mohr et al., 2021a). The absence of touch resulted in a yearning for it (Beßler et al., 2020) and was linked to higher levels of stress, anxiety (Floyd, 2014), depression (Stein & Sanfilipo, 1985), and loneliness (Heatley Tejada et al., 2020). Similar to such external factors that can impact the availability of touch, age could also play a part. While younger individuals tend to prefer closer proximity and more frequent touch (Upenieks & Schafer, 2022), older adults rate touch as more pleasant (Sehlstedt et al., 2016) and describe it using more emotional language (Guest et al., 2014), suggesting an increased appreciation with age. This might be due to cognitive evaluation, where the reduced frequency of touch in daily life enhances its enjoyment, and potentially, its impact on health. Evidence suggests that increasing age is associated with a higher benefit through touch for systolic blood pressure (Packheiser et al., 2024a). Despite its importance, interpersonal touch is not consistently measured as part of social support, leaving significant gaps in understanding its full effects. Thus, little is known about the association between interpersonal touch and health in older adults.

In our previous study (Navyte et al., 2024), we attempted to untangle the relationship between touch frequency with romantic partners versus other close adults and allostatic load in the ageing population, using the National Social Life, Health, and Aging Project (NSHAP) dataset. Firstly, we found that allostatic load in this population did not operate as a single unified system but rather as three distinct systems: metabolic, cardiovascular, and neuroendocrine. Each of these systems reflects the level of allostatic load specific to that system, rather than an overall measure. We found that increased touch frequency with romantic partners was positively associated with enhanced neuroendocrine health. This was measured through pulse rate and dehydroepiandrosterone (DHEA) levels, collected concurrently with subjective reports of touch frequency over the preceding 12 months. These findings suggest that physical touch between romantic partners is linked to reduced neuroendocrine system burden, as indicated by lower levels of stress-related hormones such as DHEA. However, it is unclear if this relationship holds over time. There is a notable shortage of longitudinal studies investigating the association between touch frequency and physiological health outcomes in adults. One such study by Thomas and Kim (2021) found that frequent physical touch is associated with a reduced likelihood of elevated chronic inflammation over time, indicating the lasting benefits of touch on health. Additionally, some evidence supports improved mental health outcomes in adults over time (Brown et al., 2021; Weze et al., 2007)

Building on our previous cross-sectional research (Navyte et al., 2024), where we found a positive association between increased touch frequency with romantic partners and improved neuroendocrine health at the same time point, this study takes the inquiry further by exploring longitudinal associations.. Cross-sectional designs are limited in determining whether improved health causes or results from increased touch frequency. To address this, we will investigate how touch frequency from both romantic partners and other close adults relates to metabolic, cardiovascular and neuroendocrine health outcomes five years later. Additionally, we will examine whether worse metabolic, cardiovascular, and neuroendocrine health at the initial time point is associated with touch frequency five years later, aiming to rule out the possibility that health status influences touch frequency over time. We hypothesise that (1) more frequent physical touch will be associated with better health outcome compared to less frequent touch, and (2) this relationship between frequent touch and health outcomes will be stronger for touch with romantic partners compared to other close adults.

Methods

Participants

We utilised data from the National Social Life, Health and Aging Project (NSHAP), a longitudinal survey investigating the multifaceted influences on health and ageing among older adults in the United States. This population-based study collected data from community-dwelling older adults via face-to-face interviews, the collection of biological samples, and the distribution of leave-behind questionnaires among a randomly selected subset of respondents. The survey adopted an oversampling approach for black, Hispanic, and oldest age individuals (75-85 years), employing a complex, multistage area probability sampling design with post stratification.

This analysis uses data from Wave 1 and Wave 2 of the NSHAP, conducted from 2005 to 2006 and 2010 to 2011, respectively. Wave 1 included 3,005 adults aged 57-85 years (1,455 men and 1,550 women), with an overall response rate of 75.5%. Wave 2 included 3,377 adults aged 62-91 years, comprising respondents from Wave 1, their spouses/partners, and individuals who were sampled but did not participate in Wave 1. Among Wave 2 respondents, 2,261 were also respondents in Wave 1 (1,085 men and 1,176 women). Non-participation in Wave 2 among Wave 1 respondents was attributed to death, relocation, or health issues precluding participation. The overall response rate for Wave 2 was 76.1%. Biomarker collection was conducted at both waves, though limited to a subset of respondents during each wave.

To our knowledge, the NSHAP is the sole nationally representative survey encompassing longitudinal assessments of both non-sexual touch between adults and biomarkers. For our analyses, we used both Wave 1 and Wave 2. Our analytic sample comprises 787 respondents from Wave 2 who also participated in Wave 1 and had complete outcome data across both waves. A comparison of the analytic sample and the non-analytic (n=1,474) characteristics can be found in Appendix Table B.1.

Touch Frequency

Touch frequency was assessed using four questions, two from the Wave 1 questionnaire and two from the Wave 2 questionnaire, which measured touch frequency with romantic partners and other close adults. In Wave 1, respondents were asked “In the last 12 months, how often have you engaged in the following activities: hugging, kissing, caressing, or other close physical contact with your partner?” and “In the last 12 months, how often have you engaged in the following activities: hugging, holding, or other close physical contact with another adult?”. The NSHAP defined “other adults” in Wave 1 as family members, neighbours and friends.

In Wave 2, the wording of these questions was modified. Respondents were asked, “In the last 12 months, how often have you engaged in the following activities? How often have you or your partner shared caring touch, such as a hug, sitting or lying cuddled up, a neck rub or holding hands?” and “Other than your partner, how often have you and a person, such as a friend, grandchild or another adult, shared caring touch, such as a greeting hug, a touch on the arm, or a neck rub? (In the last 12 months, how often have you engaged in the following activities?)”. Each question, from each wave, was treated as an independent exposure variable representing touch frequency with different individuals at time points 1 and 2.

In Wave 1, respondents answered using a 7-point scale ranging from 0 (never) to 6 (several times a week), while in Wave 2, they used a 7-point scale ranging from 0 (never) to 6 (many times a day). For the analysis at hand, responses were regrouped into four categories: 1 (never), 2 (once a month), 3 (once a week), and 4 (several times a week).

Allostatic Load (AL)

For this analysis, we created three latent variables – metabolic health (C-reactive protein (CRP), Glycosylated Haemoglobin (HbA1c), Body Mass Index (BMI), and Waist Circumference), cardiovascular health (Systolic Blood Pressure (sBP) and Diastolic Blood Pressure (dbp)), and neuroendocrine health (Dehydroepiandrosterone (DHEA) and Pulse) – at both Wave 1 and Wave 2. These latent variables were derived using principal components analysis (PCA) of AL biomarkers as described in our previous study (Navyte et al., 2024).

The NSHAP dataset includes eight AL biomarkers in Waves 1 and 2, which were used in our earlier research (Navyte et al., 2024) to align closely with markers used in previous studies. These biomarkers at both waves are presented in Chapter 2 Table 2.1. Since only two observed variables were used for the latent variables of cardiovascular and neuroendocrine health, their indicators were constrained to be equal. To achieve normality, HbA1c, CRP, and DHEA were log-transformed based on data inspection. All eight biomarkers in Waves 1 and 2 were standardised to have a mean of 0 and a standard deviation of 1. This standardisation allows for direct comparison between different biomarkers, regardless of their original units or scales, and facilitates the interpretation of results in a consistent and comparable manner.

Covariates

Sexual Touch. Sexual touch was originally categorised into three groups: (1) no sex in the last 12 months, (2) infrequent sexual touch, and (3) frequent sexual touch. These categories were derived based on responses to two questions:

1. “Had sex in the last year?” with responses of yes or no.
2. For those who answered yes, “When you had sex with your partner in the last 12 months, how often did your activities include kissing, hugging, caressing, or other ways of sexual touching?” Responses were provided on a 5-point scale from 1 (never) to 5 (always).

Respondents who reported always engaging in sexual touching during their sexual encounters were categorised as having ‘frequent’ sexual touch, while all other respondents were categorised as having ‘infrequent’ sexual touch. For this analysis, only Wave 1 sexual touch data was used and converted to a continuous variable to capture the full range of variation. This approach ensured the temporal relationship between predictors and outcomes was maintained.

Alcohol Intake. Three questions: ‘Have you ever drunk alcohol?’, ‘Do you drink alcohol?’ and ‘How many days per week do you drink?’ were combined to create three groups: (1) regular drinkers (intake at least one day per week), (2) non-regular drinkers (intake less than one day a week), and (3) never drank alcohol.

Household Composition. Number of co-residents was initially a categorical variable with three groups: (1) lives alone, (2) lives with one other person, and (3) lives with two or more persons. For this analysis, only Wave 1 household composition was used, and treated as a continuous measure.

Romantic Partner. The romantic partner variable was binary. One group comprised individuals who were in a romantic relationship at the time of Wave 1 data collection, including those who were married, cohabiting, or involved in a romantic, intimate, or sexual relationship. The other group consisted of individuals who were not in a romantic relationship at the time of the Wave 1 survey, including those who were separated, divorced, widowed, never married, and not involved in a romantic, intimate or sexual relationship. Only Wave 1 romantic partner data was utilised in the analysis.

Sociodemographic Characteristics. All sociodemographic variables used were from Wave 1, however total household assets were only measured at wave 2. Sex and ethnicity were measured as binary variables: men and women; white and non-white (including black and Hispanic respondents). Age was initially categorised into three groups: (1) 57-64, (2) 65-74, and (3) 75-85 years in descriptive analyses, but it was transformed into a continuous variable for multivariate analysis.

Social economic position (SEP) combined total household assets (property, cars, businesses, financial assets etc.) and educational attainment. Educational attainment was initially a categorical variable with four groups: (1) less than high school, (2) high school degree or equivalent, (3) some college or associate degree, and (4) bachelor’s degree or higher. Total household assets were also categorised into four groups: (1) $0-49,999, (2) $50,000-99,999, (3) $100,000-499,999, and (4) $500,000 or more. Both educational attainment and total household assets were transformed into continuous variables in multivariate analysis.

Statistical Analyses

A structural equation modelling (SEM) approach was employed to explore the relationships between romantic partner touch frequency and touch frequency with other close adults, and three latent health outcome variables: metabolic health, cardiovascular health, and neuroendocrine health, across two waves of the NSHAP using cross-lagged path modelling. These latent variables were constructed based on the findings of a PCA in our previous study (Navyte et al., 2024). Each health outcome was modelled as a latent variable at both Wave 1 and 2 of the NSHAP.

1. **Metabolic Health:** Latent variables at both waves included scaled waist circumference, scaled and log-transformed CRP, scaled and log-transformed HbA1c, and scaled BMI.
2. **Cardiovascular Health:** Latent variables at both waves included scaled SBP and scaled DBP.
3. **Neuroendocrine Health**: Latent variables at both waves included scaled log-transformed DHEA and scaled pulse rate.

The cross-lagged path models specified that each latent outcome variable at Wave 2 was predicted by its corresponding latent variable at Wave 1 and the continuous touch frequency (either romantic partner or other close adult) at Wave 1. Additionally, touch frequency at Wave 2 was regressed on touch frequency at Wave 1 and the latent variables at Wave 1.

Sociodemographic characteristic (age, sex, ethnicity, educational attainment, and household assets) were included in the minimally adjusted 'base' model. Further adjustments were made in additional models to include household composition, romantic partner status (only for touch frequency with other close adults models), sexual touch, and alcohol intake. This resulted in a total of five models for each combination of health outcome (metabolic, cardiovascular, and neuroendocrine health) and touch frequency source (romantic partner and other close adults).

The models were fitted using the 'sem' function from the 'lavaan' package in R, employing full information maximum likelihood (FIML) to account for missing data as recommended for structural equation modelling for NSHAP data (Hawkley et al., 2014). Model fit was assessed using standard fit indices and the explained variance (R-squared) for the endogenous variables.

Survey weights were not applied in the cross-lagged path models to preserve statistical power. Applying survey weights could further reduce the effective sample size and increase variability, potentially compromising the robustness of the results. The NSHAP does not yet have a true panel weight (currently in progress) for longitudinal analyses.

Results

Participant Characteristics

Table 3.1 shows the relationship between touch frequency (from romantic partners and other adults), sociodemographic variables and covariates in the final sample (n = 787) from NSHAP Wave 1 and 2.

Table 3.1. *The relationship between touch frequency (from romantic partners and other adults), sociodemographic variables and covariates in the final sample (n = 787) from NSHAP Wave 1 and 2*

Demographic Characteristic	**Wave**	**Partner Touch Frequency (%)**				**Touch with Others Frequency (%)**			
		Never	Monthly	Weekly	>Weekly	Never	Monthly	Weekly	>Weekly
Sex									
Women[a]	1	50.00	38.98	42.55	35.54	37.17	42.60	60.24	60.76
	2	68.18	38.30	30.00	33.55	30.61	38.67	53.80	54.73
Ethnicity									
White[b]	1	25.00	62.07	75.56	85.18	70.59	82.03	77.78	74.03
	2	68.18	73.33	71.79	85.43	57.14	85.03	83.66	75.23
Age (y)									
57-64	1	37.50	38.98	42.55	43.38	34.55	40.81	35.54	36.71
65-74	1	37.50	37.29	44.68	38.48	41.88	35.87	37.95	45.57
75-85	1	25.00	23.73	12.77	18.14	23.56	23.32	26.51	17.72
62-69	2	45.45	48.94	45.00	42.58	28.57	40.00	32.91	37.57
70-79	2	31.82	44.68	32.50	41.29	42.86	36.67	37.97	44.38

80-91	2	22.73	6.38	22.50	16.13	28.57	23.33	29.11	18.05
Educational Attainment									
<High School	1	37.50	23.73	10.64	12.99	18.85	14.80	16.27	18.99
	2	13.64	14.89	15.00	13.23	32.65	13.33	11.39	18.64
High School Degree or Equivalent	1	12.50	32.20	29.79	24.75	30.89	26.46	18.07	21.52
	2	36.36	23.40	27.50	23.55	28.57	28.67	25.32	21.89
Some College or Associate Degree	1	37.50	32.20	25.53	32.35	32.46	29.15	36.14	33.54
	2	36.36	36.17	35.00	32.58	26.53	27.33	39.87	32.25
Bachelor's Degree or Higher	1	12.50	11.86	34.04	29.90	17.80	29.60	29.52	25.95
	2	13.64	25.53	22.50	30.65	12.24	30.67	23.42	27.22
Total Household Assets ($)[c]									
0-49,999	2	50.00	10.87	11.43	9.22	19.26	15.03	8.33	22.43
50,000-99,999	2	16.67	8.70	5.71	7.45	10.37	8.67	12.04	13.08
100,000-499,999	2	16.67	54.35	42.86	37.94	36.30	45.09	42.59	31.78
500k or higher	2	16.67	26.09	40.00	45.39	34.07	31.21	37.04	32.71
Number of co-residents									
Lives Alone	1	0.00	6.78	4.26	6.63	21.47	27.48	25.90	24.68
	2	4.55	0.00	0.00	0.32	20.41	20.00	29.75	20.71
Lives with One Other Person	1	87.50	67.80	74.47	74.45	60.21	55.41	54.22	51.27
	2	72.73	76.60	75.00	83.23	44.90	66.00	54.43	48.52
Lives with Two or More Persons	1	12.50	25.42	21.28	18.92	18.32	17.12	19.88	24.05
	2	22.73	23.40	25.00	16.45	34.69	14.00	15.82	20.71

Romantic Partner[d]									
Yes	1					74.87	69.06	69.28	68.35
	2					55.10	73.33	65.19	62.13
Frequency of Sexual Touch									
No Sex	1	62.50	41.82	37.21	20.87	46.45	41.78	41.72	47.02
	2	78.95	56.82	30.56	28.31	36.36	42.86	34.83	33.33
Infrequent Sexual Touch	1	25.00	25.45	23.26	11.96	11.48	13.62	8.59	11.92
	2	10.53	22.73	33.33	12.50	9.09	18.37	19.10	11.70
Frequent Sexual Touch	1	12.50	32.73	39.53	67.18	42.08	44.60	49.69	41.06
	2	10.53	20.45	36.11	59.19	54.55	38.78	46.07	54.97
Alcohol Intake									
Never Drank	1	14.29	18.60	13.51	9.84	16.80	11.05	15.27	23.01
	2	21.05	23.08	16.67	15.58	24.24	10.38	16.13	22.76
Non-Regular Drinker	1	57.14	23.26	29.73	26.56	39.20	26.52	25.95	23.89
	2	15.79	30.77	6.67	22.51	27.27	26.42	28.23	24.80
Regular Drinker	1	28.57	58.14	56.76	63.61	44.00	62.43	58.78	53.10
	2	63.16	46.15	76.67	61.90	48.48	63.21	55.65	52.44

Note.

[a] Compared to men

[b] Compared to black and Hispanic respondents

[c] Only measured at Wave 2

[d] Compared to no romantic partner available

Table 3.2 presents the results from the cross-lagged path models predicting latent health outcome variables (metabolic, cardiovascular, and neuroendocrine) and touch frequency (with romantic partners and other close adults at wave 1 and wave 2). Standardised regression coefficients are presented for latent health outcome variables and touch frequency.

Table 3.2. *Cross-lagged path models predicting touch frequency (with romantic partners and other close adults) and latent health outcomes (metabolic, cardiovascular, and neuroendocrine)*

Predictors	**Wave 2 Metabolic Health**		**Wave 2 Cardiovascular Health**		**Wave 2 Neuroendocrine Health**		**Wave 2 Romantic Partner Touch Frequency**		**Wave 2 Other Close Adult Touch Frequency**	
	B	95% CI	*B*	95% CI	*B*	95% CI	*B*	95% CI	*B*	95% CI
Wave 1 Metabolic Health										
Model 1 (base model)	1.01**	0.96-1.07					-0.01	-0.10-0.09	0.07	-0.02-0.16
Model 1 + household composition (Model 2)	1.01**	0.96-1.07					-0.01	-0.11-0.09	0.07	-0.02-0.16
Model 2 + romantic partner availability (Model 3)	1.01**	0.95-1.06					-0.01	-0.11-0.09	0.07	-0.02-0.15
Model 3 + sexual touch (Model 4)	1.01**	0.95-1.06					-0.01	-0.11-0.09	0.07	-0.02-0.16
Model 4 + alcohol intake (Model 5)	1.00**	0.95-1.06					-0.00	-0.10-0.09	0.07	-0.02-0.16

Wave 1 Cardiovascular Health										
Model 1 (base model)			0.60**	0.51-0.69			0.003	-0.11-0.11	-0.02	-0.13-0.08
Model 1 + household composition			0.60**	0.51-0.69			0.01	-0.11-0.12	-0.02	-0.13-0.08
Model 2 + romantic partner availability (Model 3)			0.60**	0.51-0.69			0.01	-0.11-0.12	-0.02	-0.13-0.08
Model 3 + sexual touch (Model 4)			0.60**	0.51-0.69			0.01	-0.10-0.12	-0.02	-0.13-0.08
Model 4 + alcohol intake (Model 5)			0.60**	0.51-0.69			0.01	-0.10-0.12	-0.02	-0.13-0.09
Wave 1 Neuroendocrine Health										
Model 1 (base model)					1.57**	0.55-2.58	0.15	-0.42-0.73	0.01	-0.51-0.54
Model 1 + household composition					1.57**	0.56-2.59	0.15	-0.42-0.72	0.01	-0.51-0.54
Model 2 + romantic partner availability (Model 3)					1.56**	0.55-2.56	0.15	-0.43-0.72	0.00	-0.52-0.52

Model 3 + sexual touch (Model 4)					1.56**	0.55-2.57	0.15	-0.42-0.72	-0.01	-0.53-0.52
Model 4 + alcohol intake (Model 5)					1.57**	0.55-2.58	0.12	-0.46-0.69	0.01	-0.51-0.53
Wave 1 Romantic Partner Touch Frequency										
Model 1 (base model)	-0.07**	-0.13- -0.02	-0.11*	-0.21- -0.02	0.03	-0.05-0.10	0.65**	0.55-0.75		
Model 1 + household composition	-0.07**	-0.13- -0.02	-0.11*	-0.21- -0.02	0.02	-0.05-0.10	0.65**	0.55-0.75		
Model 2 + romantic partner availability (Model 3)	-0.07**	-0.13- -0.02	-0.11*	-0.21- -0.02	0.02	-0.05-0.10	0.65**	0.55-0.75		
Model 3 + sexual touch (Model 4)	-0.08**	-0.13- -0.02	-0.14**	-0.23- -0.04	0.04	-0.04-0.12	0.63**	0.52-0.74		
Model 4 + alcohol intake (Model 5)	-0.08**	-0.13- -0.02	-0.14**	-0.23- -0.04	0.04	-0.04-0.12	0.63**	0.52-0.74		
Wave 1 Other Close Adult Touch Frequency										
Model 1 (base model)	-0.00	-0.03-0.03	0.01	-0.05-0.06	0.03	-0.02-0.07			0.23**	0.17-0.30

Model 1 + household composition	-0.00	-0.03-0.03	0.01	-0.05-0.06	0.02	-0.02-0.07			0.24**	0.17-0.30
Model 2 + romantic partner availability (Model 3)	-0.00	-0.03-0.03	0.01	-0.05-0.06	0.02	-0.02-0.07			0.24**	0.17-0.30
Model 3 + sexual touch (Model 4)	-0.00	-0.03-0.03	0.00	-0.05-0.06	0.02	-0.02-0.07			0.23**	0.16-0.30
Model 4 + alcohol intake (Model 5)	-0.00	-0.03-0.03	0.01	-0.05-0.06	0.03	-0.02-0.07			0.23**	0.17-0.30

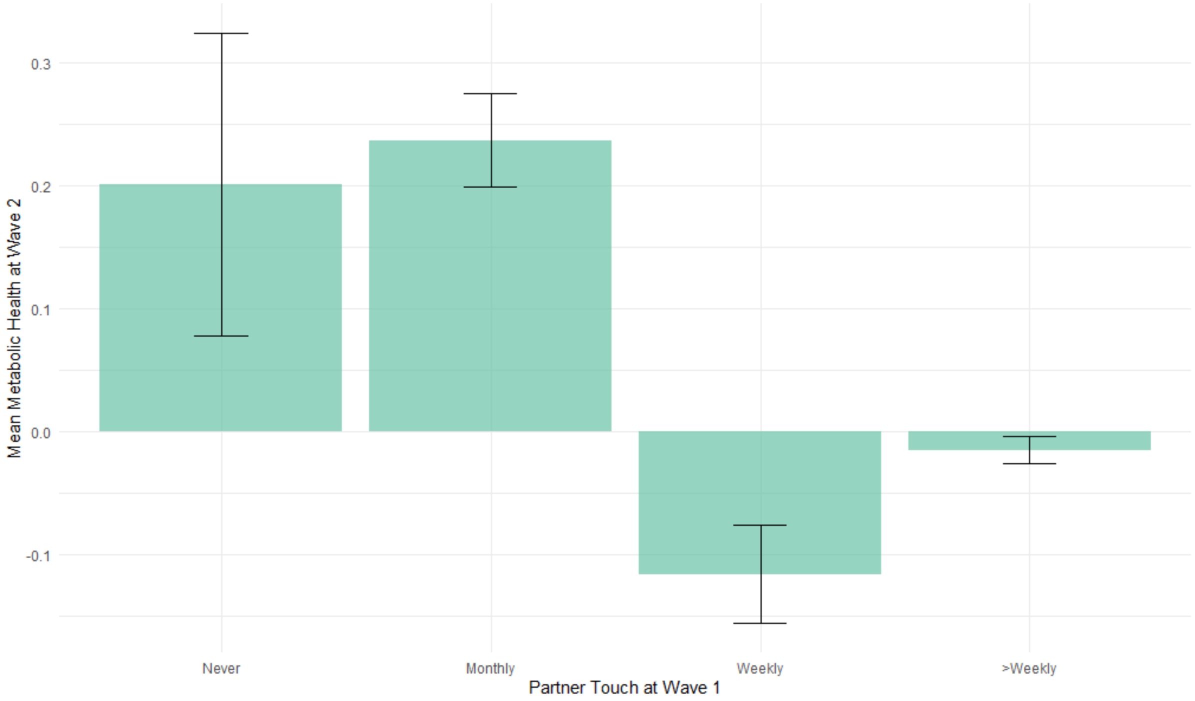
Note. The base model is adjusted for sociodemographic characteristics (age, sex, ethnicity, and SEP). Negative *B* values indicate better health. Conversely, positive *B* values indicate worse health, suggesting more load on the respective system. *p < .05. **p< .01

Metabolic Health

The findings indicate that more frequent touch with romantic partners at Wave 1 is significantly associated with better metabolic health 5 years later (model 5: *b* = -0.08, *p* = .006) (see Figure 3.1). This relationship holds from the base model, which adjusts for sociodemographic characteristics and lagged metabolic health, through to the final model adjusted for all covariates (see Table 3.2). Specifically, each unit increase in romantic partner touch frequency (e.g., from ‘Never’ to ‘Monthly’) corresponds to a 0.08 standard deviation improvement in the metabolic health composite score at Wave 2.

As expected metabolic health at Wave 1 is significantly associated with metabolic health at Wave 2 (model 5: *b* = 1.00, *p* = <.001), indicating that better metabolic health at Wave 1 is associated with better metabolic health at Wave 2. However, metabolic health at Wave 1 is not associated with touch frequency at Wave 2, either with romantic partners (model 5: *b* = -0.00, *p* = .931) or other close adults (model 5: *b* = 0.07, *p* = .132). Additionally, more frequent touch with other close adults at Wave 1 is not associated with metabolic health at Wave 2 (model 5: *b* = -0.00, *p* = .993)

Figure 3.1. *Metabolic health at Wave 2 by increasing romantic partner touch frequency at Wave 1 of the NSHAP*



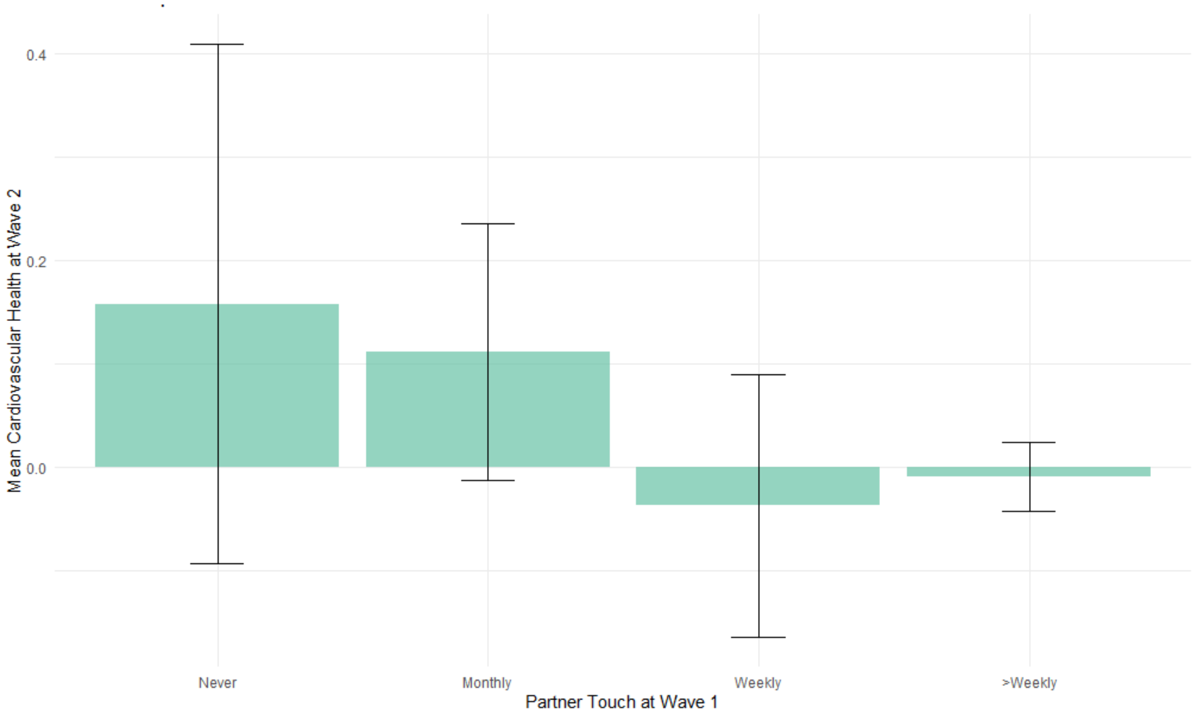
Note. Metabolic health at Wave 2 is derived from standardised values of waist circumference, CRP, HbA1c, and BMI. The Scale represents deviations from the sample mean metabolic health at Wave 2. Negative values indicate better metabolic health, with metabolic indicators below the average. Conversely, positive values indicate worse metabolic health compared to the sample mean.

Cardiovascular Health

The findings indicate that more frequent touch with romantic partners at Wave 1 is associated with better cardiovascular health 5 years later (model 5: b = -0.14, p = .005) (see Figure 3.2). This relationship holds from the base model, which adjusts for sociodemographic characteristics and lagged cardiovascular health, through to the final model adjusted for all covariates (see Table 3). Specifically, each unit increase in romantic partner touch frequency (e.g., from ‘Never’ to ‘Monthly’) corresponds to a 0.14 standard deviation improvement in the cardiovascular health composite score at Wave 2. However, more frequent touch with other close adults at Wave 1 is not associated with cardiovascular health at Wave 2 (model 5: *b* = 0.01, *p* = .851).

As expected cardiovascular health at Wave 1 is associated with cardiovascular health at Wave 2 (model 5: *b* = 0.60, *p* = <.001), indicating that better cardiovascular health at Wave 1 predicts better cardiovascular health at Wave 2. Also, cardiovascular health at Wave 1 is not associated with touch frequency at Wave 2, either with romantic partners (model 5: *b* = -0.01, *p* = .861) or other close adults (model 5: *b* = -0.02, *p* = .727).

Figure 3.2. *Cardiovascular health at Wave 2 by increasing romantic partner touch frequency at Wave 1 of the NSHAP*



Note. Cardiovascular health at Wave 2 is derived from standardised values of SBP and DBP. The scale represents deviations from the sample mean cardiovascular health at Wave 2. Negative values indicate better cardiovascular health, with cardiovascular health indicators below the average. Conversely, positive values indicate worse cardiovascular health compared to the sample mean.

Neuroendocrine Health

The findings indicate touch frequency is not associated with neuroendocrine health 5 years later, whether it was with romantic partners (model 5: $b = 0.04$, $p = .327$) or other close adults (model 5: $b = 0.03$, $p = .280$). As expected neuroendocrine health at Wave 1 is associated with neuroendocrine health at Wave 2 (model 5: $b = 1.57$, $p = .002$), indicating that better neuroendocrine health at Wave 1 predicts better neuroendocrine health at Wave 2. In addition, neuroendocrine health at Wave 1 is not associated with touch frequency at Wave 2, either with romantic partners (model 5: $b = 0.12$, $p = .690$) or other close adults (model 5: $b = 0.01$, $p = .975$).

Discussion

The results of this study revealed that frequent touch with romantic partners was associated with improved metabolic and cardiovascular health five years later. These associations remained consistent across all models, even after adjusting for sociodemographic factors and other covariates, indicating robust relationships between romantic partner touch frequency and metabolic and cardiovascular health over time. In contrast, touch frequency with other close adults did not show similar associations. Unlike metabolic and cardiovascular health, touch frequency, whether with romantic partners or other close adults, did not have an association with neuroendocrine health five years later. This suggests that the long-term benefits of frequent romantic partner touch on health may be more pronounced in metabolic and cardiovascular physiological systems than the neuroendocrine system. These results support the findings of similar studies, such as Thomas and Kim (2021), who showed that increased frequency of touch is associated with lower likelihood of chronic inflammation 5 years later.

Our previous study (Navyte et al., 2024) found that increased partner touch frequency was associated with better neuroendocrine health at the same time point. We expand these observations in the current study and observe that the long-term benefits of frequent touch with romantic partners are evident in metabolic and cardiovascular health. This aligns with the concept of allostasis, the body's process of maintaining stability by adapting to stressors (Sterling & Eyer, 1988). Repeated exposure to stress increases the body's allostatic load, the cumulative burden of chronic stress and its physiological effects (Seeman et al., 2001). High allostatic load is associated with poor cognitive and physical functioning (Karlamangla et al., 2002), cardiovascular disease (Seeman et al., 2001), and all-cause mortality (Goldman et al., 2006). Allostatic load is typically measured by aggregating primary (e.g., stress hormones) and secondary (e.g., raised blood pressure) mediators, which reflect prolonged physiological adjustments leading to disease (Seeman et al., 2001). Frequent touch with romantic partners can immediately reduce stress levels and promote relaxation (Ditzen et al., 2007), enhancing neuroendocrine health (Navyte et al., 2024). Our results suggest that over time, this repeated reduction of acute stress responses through frequent touch can lower the impact of secondary mediators, and therefore, overall allostatic load. A lower allostatic load means the body is less frequently exposed to the harmful effects of chronic stress, such as elevated cortisol, inflammation, and disrupted metabolic processes. This reduced chronic stress burden can contribute to better long-term health outcomes in other physiological systems. Specifically, our study shows that while neuroendocrine health responds quickly to stress reduction through frequent touch with romantic partners, improvements in metabolic and cardiovascular systems take longer to manifest, as they rely on the cumulative effects of reduced allostatic load over time.

Our findings on improved metabolic and cardiovascular health outcomes aligns with previous research while providing new insights through longitudinal data analysis. For cardiovascular health, which we measured through SBP and DBP, we found that individuals who frequently shared touch with romantic partners has better cardiovascular outcomes five years later. This finding is consistent with earlier studies demonstrating that interpersonal touch from a romantic partner is associated with lower blood pressure, especially in stressful situations (Guéguen, 2004; J. Holt-Lunstad et al., 2008; Lee & Cichy, 2020; Light et al., 2005). Regarding metabolic health, which we assessed using waist circumference, CRP, HbA1c, and BMI, our findings also support prior research. Individuals who reported frequent touch with romantic partners had better metabolic health five years later. This is in line with studies showing that increased touch frequency is linked to lower inflammation levels (Thomas & Kim, 2021; van Raalte & Floyd, 2021). Additionally, increased passionate kissing between romantic partners has been associated with lower total serum cholesterol (Floyd et al., 2009), and affectionate behaviours have been connected to healthier vascular and metabolic profiles, as indicated by blood pressure and HbA1c levels (Floyd et al., 2007). The results of the present study build on this body of evidence by demonstrating that these associations hold true over time, highlighting the lasting health benefits of frequent interpersonal touch with romantic partners.

The absence of associations between touch from other close adults and health outcomes suggests that the unique benefits of romantic touch are distinct and not replicated in other types of close adult interactions, as highlighted in our prior study (Navyte et al., 2024). This distinction likely arises from the deeper intensity and intimacy inherent in romantic relationships, which can lead to more profound psychological and physiological advantages. For instance, simply having a partner in close proximity, rather than a friend, has been shown to reduce threat-related activity in the amygdala over time (Morriss et al., 2019). Romantic relationships differ significantly from friendships in terms of time spent together and the depth of shared life experiences. Previous research indicates that touch from a romantic partner can effectively reduce individual stress, with relationship quality predicting up to 16.8% of the stress-alleviating effect (Liu et al., 2021). Likewise, having an attentive partner can enhance feelings of security during challenging tasks, such as walking on a precarious cliff, compared to having an inattentive partner (Kane et al., 2012). Furthermore, a touch on the hand by a romantic partner is able to buffer pain, whilst the opposite is true for strangers and friends (Floyd et al., 2018).

We found that initial health status was not significantly associated with future touch frequency, suggesting that the health benefits observed are likely due to touch itself, rather than healthier individuals engaging in more touch. This mitigates concerns about reverse causality and implies that other health-related factors, like pre-existing conditions, are not driving the relationship between touch and health outcomes. This finding strengthens the case for touch having a direct, beneficial impact on health and suggests that touch-based interventions could be effective across a wide range of health conditions, not just for those who are already healthy.

This study is the first to explore the relationship between interpersonal touch with romantic partners, compared to other close adults, and longitudinal multi-system dysregulation in older adults. However, several limitations should be acknowledged. First, individuals may differ in metabolic and cardiovascular health despite similar frequencies of partner touch by unaccounted factors like genetics, lifestyle choices (diet, exercise), other health conditions, or personal perceptions of partner touch. While many of our observations are significant at a traditionally used level , the results should be interpreted with caution, as they do not imply consistent predictions across all cases, as indicated by the error bars in Figure 1 and Figure 2. Additionally, the NSHAP survey groups touch from all non-romantic close adults into one category, overlooking potential differences in the meaning, type, and frequency of touch between different relationships. Future research should differentiate between types of non-romantic touch to determine if they have distinct associations with health. Another limitation is the variation in wording and response scales between Wave 1 and Wave 2 of the NSHAP survey, which may introduce inconsistencies in measuring touch frequency. This, along with the reliance on self-reported data, which is prone to recall and social desirability biases, could affect the accuracy of the findings. Moreover, the analysis was based on a reduced sample size (n = 787), which, despite the NSHAP's national representativeness, may not fully capture the diversity of the older adult population in the U.S. Finally, while the cross-lagged path modelling approach suggests associations over time, it cannot establish causality. Future research should aim to establish causal relationships.

Promoting touch within romantic relationships could be considered a potential health strategy aimed at improving short-term neuroendocrine health, and long-term metabolic and cardiovascular health, especially for older adults. Educating individuals about the potential health benefits of romantic partner touch could encourage behaviours that contribute to better long-term health outcomes.

4. Influence of Vicarious Hug Video Perspective and Duration on Physiological and Emotional Responses: A Mixed Effects Model Analysis

Introduction

Touch serves as a catalyst for emotional experiences in social interactions, with its inherently hedonic properties playing a pivotal role in improving well-being (Beebe-Center, 1935). The absence of touch has been repeatedly linked to negative outcomes, such as heightened stress during the COVID-19 pandemic (Field et al., 2020), increased anxiety (Floyd, 2014), higher depression rates (Stein & Sanfilipo, 1985), and greater prevalence of loneliness (Heatley Tejada et al., 2020). This highlights the importance of touch in emotional well-being, which is partly explained by the C-Tactile (CT) afferent system, a neuronal network that encodes pleasant touch sensations (Löken et al., 2009). These unmyelinated, low-threshold afferents are found in hairy skin (Vallbo et al., 1999; Wessberg & Norrsell, 1993) and have been widely studied for their role in social touch and the perception of pleasant sensations (Björnsdotter & Olausson, 2011; Walker et al., 2017). Slow stroking at 1-10 cm/s, known as CT-optimal touch, best activates these afferents, generating a sensation often associated with affiliative social interactions (Gallace & Spence, 2010; Nordin, 1990; Olausson et al., 2010). The neural processing of pleasant touches are thought to involve the "social brain" circuit (Brothers, 1990), a complex neural network specialised to support social function, including the posterior insular cortex, which responds to both the direct experience of touch and its observation. Though hugs and other forms of deep pressure touch may involve less CT-fibre activation than gentle stroking, they are found to be similarly pleasant and also show corresponding neural activations (Case et al., 2021). Deep pressure touch, such as hugs, may activate pressure-sensitive receptors in muscles and connective tissues or stimulate vagal afferents projecting to the vagal nucleus, promoting relaxation through the parasympathetic nervous system (Corey et al., 2011; Diego & Field, 2009; Graven-Nielsen et al., 2004; Hoheisel et al., 2005; Kandel et al., 2000; McGlone & Reilly, 2010; Mense & Meyer, 1985).

Vicarious touch is defined as the perception of touch through visual feedback (Haans & IJsselsteijn, 2009). Although these simulations occur implicitly, numerous studies have highlighted an inclination to vicariously recreate the actions and sensations of others in the observer’s own neural circuits (Björnsdotter & Olausson, 2011; Keysers & Gazzola, 2009; Lamm et al., 2015). This propensity may be associated with the capacity to empathise with the cognitive and emotional states of others (Vachon-Presseau et al., 2012), although the relationship between vicarious touch and empathy is mixed (Bekkali et al., 2021). Often attributed to a mirroring system, vicarious action perception was initially identified in macaque brains, where mirror neurons activated not only during the execution of an action but also while observing the same action performed by another macaque (Di Pellegrino et al., 1992; for review, see Rizzolatti et al., 2001). While the macaques mirror neuron system is activated, there might not be much empathy in macaques, so other processing is likely required, even if the mirror neuron system contributes to it.

In humans, both primary and secondary somatosensory cortices are activated through both direct tactile stimulation and upon seeing someone else’s stimulation (Blakemore et al., 2005; Keysers et al., 2004). Additionally, Molenberghs et al (2012) suggest that somatosensory regions are part of an extended mirror neuron system. Electroencephalography (EEG) studies have also reported modulated somatosensory-evoked-potentials (SEPs) not only by the direct experience but also by the observation of touch (Adler & Gillmeister, 2019; Bufalari et al., 2007; Peled-Avron & Shamay-Tsoory, 2017; Pisoni et al., 2018; Rigato, Banissy, et al., 2019; Rigato, Bremner, et al., 2019; Schirmer & McGlone, 2019). Additionally, increased mu rhythm power has been observed in response to observed touch in line-drawings of dyadic interactions (Schirmer & McGlone, 2019). Furthermore, the observation of images depicting social tactile interactions (embracing and kissing) has been reported to increase participants' subjective feelings of sociability, and to lower feelings of isolation (Campagnoli et al., 2015). This evidence points to the human capacity to simulate and understand the tactile experiences of others.

The social baseline theory (SBT) posits that when facing challenges, an individual experiences heightened vulnerability and a greater sense of risk when alone. In contrast, the presence of others in close proximity redistributes the burden of risk within the group (Coan, 2008). One study found that when married women were subjected to electric shocks, they experienced diminished neural threat when holding their partner's hand. Even holding the hand of a stranger brings about a reduction in neural threat, albeit to a lesser extent (Coan et al., 2006). Similarly, touch accelerates cortisol recovery after laboratory social stressors (Ditzen et al., 2019) and daily life stressors (Schneider et al., 2023). Thus, the presence of supportive individuals holds the capacity to serve as a stress buffer. Research also suggests the stress-buffering potential rooted in the simple act of envisioning touch, which is similar to vicarious touch in that both share a similar quality in activating affective and sensory responses associated with physical touch, despite the absence of direct tactile stimulation, suggesting an interesting possibility of vicarious touch to also buffer stress. This potential surpasses the benefits derived from imagining verbal support. Jakubiak and Feeney (2016) found that women who engaged in mental simulations of touch-based support exhibited a heightened willingness to tackle more challenging tasks compared to their counterparts envisioning verbal support. Moreover, human-to-pet and human-to-human vicarious hugs, stroking, and arm holding, have been associated with reduced perceived stress, while human-to-robot vicarious touch increased stress (Kirsch et al., 2024). These findings suggest that the advantages associated with interpersonal touch in stressful situations can be harnessed without necessitating direct physical contact. Although it remains unclear if vicarious touch is associated with similar physiological markers of stress reduction as real touch.

Affective stimuli activate the autonomic nervous system (ANS), reflecting emotional arousal (Braithwaite et al., 2013; Ivry & Mangun, 2014). Galvanic skin response (GSR) measures changes in skin conductivity due to sweating, which correlates with emotional intensity and sympathetic activity (Braithwaite et al., 2013). GSR typically increases in response to both pleasant and unpleasant stimuli compared to neutral stimuli (Lang et al., 1993). Research on GSR responses to vicarious touch is limited. Fusaro et al (2016) found that GSR significantly increased for painful touch, while no significant difference was observed between pleasant and neutral touch, indicating that stimulus salience may be a crucial factor (Armel & Ramachandran, 2003; Petkova & Ehrsson, 2008; Tieri et al., 2015). Although Fusaro et al (2016) used CT-optimal stroking to represent pleasant touch, other studies suggest that full-body vicarious touch, involves both sensorimotor and socio-affective experiences (Schirmer & McGlone, 2019). This implies that more encompassing touches, such as hugs, may enhance salience and elicit stronger vicarious experiences compared to the forearm-focused CT-optimal stroking. Additionally, Cabibihan and Chauhan (2015) found that GSR is lowest during a partners touch on the arm in stressful situations, followed by mechanical touch on the arm, and highest in the absence of touch. However, it remains unclear whether explicitly pleasant, full-body vicarious touch, such as hugs, might also increase GSR due to greater salience and whether such vicarious touch exhibits protective effects during subsequent stress, as indicated by lower GSR responses.

Pupillometry is another well-established method for measuring ANS activity (Bali & Jaggi, 2015; Partala & Surakka, 2003; Qin et al., 2012; Ren et al., 2014; Steinhauer et al., 2004; Yamanaka & Kawakami, 2009; Zhai & Barreto, 2008). Pupil dilation occurs within 200ms of increased norepinephrine release, triggered by stress or heightened cognitive and emotional arousal, with recovery time depending on arousal intensity (Sirois & Brisson, 2014). Beyond this, pupil dilation also reflects attentional focus, increasing in response to rewarding or salient events and correlating with heightened neural activity in sensory processing regions (Beatty, 1982; Ganea et al., 2020; Iriki et al., 1996; Laeng et al., 2012; Lee & Margolis, 2016). Tactile stimuli, whether pleasant (soft velvet and artificial fur) or unpleasant (sandpaper), typically cause greater pupil dilation compared to neutral stimuli (polylactic materials, wood, copper, and titanium powder) (Bertheaux et al., 2020). Human touch tends to elicit larger pupil responses than mechanical touch, suggesting a mechanism for social bonding (Ellingsen et al., 2014). Although research on vicarious touch is limited, increased pupil dilation has been observed in response to witnessing pain in others, indicating an autonomic orienting response and empathic concern (Azevedo et al., 2013; Chiesa et al., 2015). Moreover, holding a spouse’s hand has been shown to reduce pupil dilation during stressful tasks (Graff et al., 2019). However, whether pupil responses to pleasant vicarious touch mirror those of real touch, or if vicarious touch can similarly modulate dilation during stress, remains unclear.

While heart rate (HR) and heart rate variability (HRV) responses to vicarious touch remain largely unexplored, one study comparing vicarious pain and vicarious CT-optimal touch found a reduction in HR in a time window of six seconds after the stimulus for both pain and pleasure in comparison to neutral stimulus, for both first-person and third-person perspectives (Fusaro et al., 2016). Additionally, the effects of real touch are well documented. Real touch has been shown to decrease HR across various contexts, including stroking (Triscoli, Croy, Olausson, et al., 2017), massages (Lindgren et al., 2010), and even light touch on the wrist (Nilsen & Vrana, 1998). In infants, gentle caressing maintains a calm physiological state as indicated by stable HRV, while tapping reduces HRV (Della Longa et al., 2021). After stress, partner handholding has been found to increase HRV (Conradi et al.,

2020) and accelerate cortisol recovery (Ditzen et al., 2019; Schneider et al., 2023). Based on these effects of real touch, we might expect vicarious touch to similarly decrease HR without significantly altering HRV, thereby maintaining a calm physiological state. Additionally, vicarious touch could potentially reduce HR and HRV stress responses and enhance post-stress recovery, consistent with findings that human-to-human and human-to-pet vicarious touch has previously been linked to reduced perceived stress (Kirsch et al., 2024).

Notably, the processing of vicarious touch varies by its emotional connotation. For instance, touch with affective meaning, such as caressing or slapping, elicits stronger activations in both primary and secondary somatosensory cortices compared to touch devoid of emotional connotations (Ebisch et al., 2011). This neural response highlights the brain's heightened sensitivity to touch stimuli accompanied by emotional significance. Moreover, facial electromyography (EMG) studies have uncovered a positive valence associated with vicarious touch. Specifically, studies have revealed a reduction in frowning muscle activity (Ree et al., 2019) coupled with an increase in smiling muscle activity (Pawling et al., 2017) in response to CT-optimal touch. A well-established method for assessing facial expressions of emotion is the Facial Action Coding System (FACS), developed by Ekman and Friesen (1976). This anatomically based system enables human coders to systematically analyse facial expressions by observing 46 distinct action units (Ekman & Friesen, 1976). More recently, automated software solutions like Affectiva Affdex (iMotions, 2015) have emerged, offering faster and more accessible analysis of facial expressions than FACS coding.

Additionally, when touch is perceived as being located on the observer's own body, vicarious touch responses tend to be stronger due to a heightened sense of self-relatedness (Cardini et al., 2011). For example, Saxe et al (2006) found that viewing body areas from a first-person perspective elicited greater somatosensory cortex activation compared to a third-person perspective. Similarly, Fusaro et al (2016) reported higher illusory ownership of a virtual hand when seen from a first-person perspective compared to third-person. Vicarious touch effects were also observed only for human hands, not rubber gloves, at early somatosensory processing stages (P45), while later cognitive stages (late positive complex, LPC) showed stronger effects for self-relatable touches (human hands) compared to non-relatable ones (rubber gloves) (Adler & Gillmeister, 2019). Additionally, earlier ERP effects of vicarious touch were found for first-person perspective than third-person perspective touch (Rigato, Bremner, et al., 2019). Furthermore, earlier event-related potentials (ERPs) indicate stronger neural responses when individuals observe touch on their own face compared to another person's face (Adler et al., 2016). It remains unclear whether the perspective of full-body interactions influences vicarious experiences in the same way that simulating a specific area of the body does. Moreover, another influential determinant could be the duration of exposure to vicarious touch stimuli. Research indicates that longer hugs lasting for 10 seconds are rated as more pleasant than shorter 5-second hugs (Dueren et al., 2021). This notion potentially extends to the realm of observed touch as well.

Finally, the existing body of vicarious touch literature heavily concentrates on the examination of CT-optimal and non-CT-optimal velocities of forearm stroking. However, it is important to note that such controlled stimuli may not accurately represent the multifaceted nature of touch experiences in real-world scenarios. Although vicarious touch is rated as more pleasant when delivered at CT-optimal compared to non-CT optimal velocities (Bellard et al., 2022; Bellard et al., 2023; Devine et al., 2020; Haggarty et al., 2021; Walker et al., 2017), the prevailing "social touch hypothesis" proposes that CT-fibres are sensitive to a range of tactile stimulus features that are most likely encountered during close interpersonal interactions (Morrison et al., 2010; Olausson et al., 2010). Recent investigations have indicated that individuals intuitively adopt CT-optimal stroking velocities when engaging in tactile interactions with their partners or babies, as opposed to artificial objects (Croy et al., 2016). Additionally, studies have discovered that the observation of touch within full-body social interactions yields mirroring effects (Schirmer & McGlone, 2019), and more recent findings show that human-human hugging videos and human-pet videos were perceived as pleasant and calming (Kirsch et al., 2024). This highlights the need to expand our understanding beyond isolated stimuli and delve into the complex interplay of vicarious touch depicting naturalistic social touches.

The physiological responses to interpersonal vicarious touch, especially naturalistic interactions like hugs, are largely unexplored, both during the experience and in relation to stress, including post-stress recovery. It also remains unclear whether features like perspective and duration of vicarious touch elicit stronger physiological responses. This study aims to address these gaps by measuring physiological responses to vicarious hugs that vary by perspective (first-person, third-person) and duration (10 or 30 seconds), in comparison to neutral hugs depicting hugging a water bottle. Participants undergo the Stroop task, to elicit psychological stress (Stroop, 1935), following exposure to one of these six hug videos, and their physiological responses are also recorded during a post-stress recovery period while watching a moving clouds video. The physiological measures used will be heart rate (HR) and galvanic skin response (GSR), both of which will assess arousal (Braithwaite et al., 2013; Ivry & Mangun, 2014; Lang et al., 1993). Heart rate variability (HRV) will be used to gauge stress and relaxation (Conradi et al., 2020; Ditzen et al., 2019; Schneider et al., 2023). Pupil dilation (PD) will measure cognitive and emotional arousal (Bertheaux et al., 2020; Sirois & Brisson, 2014). Finally, Affectiva Affdex will track emotional valence, specifically focusing on joy (iMotions, 2015; Pawling et al., 2017).

We hypothesise that during video watching, participants watching first- and third-person perspective vicarious hug videos will exhibit distinct physiological responses compared to those watching neutral hug videos. Specifically, we expect higher GSR, indicating stronger sensorimotor and socio-affective engagement associated with full-body interpersonal vicarious touch (Schirmer & McGlone, 2019), similar to responses seen with salient vicarious pain stimuli (Fusaro et al., 2016). Greater PD is predicted for first- and third-person vicarious hugs due to their interpersonal nature (Ellingsen et al., 2014). Lower HR is anticipated for first- and third-person vicarious hugs due to their expected calming effects (Fusaro et al., 2016; Jakubiak & Feeney, 2016), but we do not expect significant changes in HRV, suggesting maintenance of a calm physiological state, whereas a decrease in HRV may be observed during neutral hugs videos due to their non-affective nature (Della Longa et al., 2021). Joy levels, are expected to increase in response for first- and third-person perspective vicarious hugs due to positive valence (Pawling et al., 2017). Stronger physiological responses are anticipated for first-person perspectives due to heightened self-relatedness (Fusaro et al., 2016; Saxe et al., 2006) and longer exposure, which enhance emotional engagement and arousal (Dueren et al., 2021).

During the Stroop task and subsequent recovery, we hypothesise that participants who watched first- and third-person perspective vicarious hugs will exhibit lower GSR compared to those who viewed neutral hug videos, consistent with findings that GSR is lowest during human touch in a stressful task (Cabibihan & Chauhan, 2015). We also expect lower PD during the stressful task and recovery for those who viewed first-person and third-person videos versus neutral videos, aligning with findings that holding a partner’s hand reduces pupil dilation under stress (Graff et al., 2019). Additionally, we anticipate lower HR and higher HRV during the Stroop and during stress recovery for individuals who watched first- and third-person perspective hugs compared to neutral hugs, in line with evidence of the stress buffering nature of real hugs (Conradi et al., 2020; Ditzen et al., 2019; Schneider et al., 2023). Finally, due to the protective mechanisms associated with positive vicarious touch (Kirsch et al., 2024), we anticipate joy levels to decrease less during stress and recovery compared to those watching neutral videos. One again, we anticipate stronger responses in first-person perspectives due to heightened self-relatedness (Fusaro et al., 2016; Saxe et al., 2006) and longer exposure, which enhance emotional engagement and arousal (Dueren et al., 2021).

Methods

Participants

267 participants were recruited for this study using opportunity sampling, advertisement, and an existing volunteer database. For four participants, we encountered technical errors making their data unavailable for analysis. In the combined dataset there were 263 healthy volunteers (151 female) between 18 and 86 years old (mean = 39.76; SD: 19.48). 48.67% were white, 31.94% were Asian/Asian British or American, 15.97% were black/African/Caribbean/black British or American, 1.14% were mixed/multiple ethnic groups, 0.38% were Latino, and 1.52% preferred not to say. Most (238) were right-handed. All participants gave their informed written consent to participate in this study prior to testing. All participants were rewarded with £10 cash for taking part in the study. This study was conducted in accordance with the Declaration of Helsinki (1964) and was approved by the local ethics committee.

The sample size was based on an a priori power analysis conducted using G*Power version 3.1.9.2 (Faul et al., 2007) to determine the sample size necessary to detect a conservative medium effect ($f = .25$, as outlined by Cohen (2013)), with a significant criterion of a = .05 and power = 0.80. The sample needed with this effect size is N = 216.

Materials

A Stone Intel core i7 9th generation computer with a 24” monitor was used to present visual stimuli. Version 9.3 of iMotions was used to collect physiological responses, including heart rate (HR), heart rate variability (HRV), galvanic skin response (GSR), pupil dilation (PD), along with a joy metric. An external Logitech HD Pro webcam (C920) was used for facial expression analysis recordings. Screen brightness was set to 75%.

Questionnaires. All questionnaires were presented in Qualtrics (Qualtrics, Provo, UT) in the order presented below.

Sociodemographic Characteristics. In the sociodemographic characteristics questionnaire, participants responded on their age (a continuous, numerical variable), sex as a binary variable (men and women), ethnicity (a categorical variable: white (reference level), Asian British or American, Black/African/Caribean/Black British or American, and other, including Latino, mixed/multiple ethnic groups, and prefer not to say). Education level (a categorical variable: GCSEs or below, AS/A level or vocational training, and Bachelor's degree or higher (reference level)), and having a romantic partner (Yes/No).

Touch Pleasantness. After each vicarious touch video, participants were asked "How pleasant did you find the observed touch to be?" they responded on an 8-point Likert type scale (1 = extremely unpleasant, 5 = neutral, 9 = extremely pleasant). This was treated as a continuous variable.

Social Touch Questionnaire. Participants completed the Social Touch Questionnaire (STQ) developed by Wilhelm et al. (2001). The STQ serves as a self-report instrument designed to assess an individual's inclination and reaction towards situations involving interpersonal touch. By responding to statements like "I feel uncomfortable when someone I don't know very well hugs me" or "I get nervous when an acquaintance keeps holding my hand after a handshake" participants provided insights into their sensitivity to social touch. Participants were asked to "indicate how characteristic or true each of the following statements is of you" on a 0-4 scale (0 = not at all, 1 = slightly, 2 = moderately, 3 = very, 4 = extremely). A total score is calculated using the sum of the responses to all 20 questions.

Scores on this scale are inversely related to the degree of preference for social touch; thus, lower scores indicate a stronger affinity for social touch, while higher scores signify a heightened aversion to engaging in, receiving, or observing social touch interactions. In this sample, internal consistency (Cronbach's α) of the scale was 0.83, indicating good internal consistency.

Touch Deprivation Scale. Participants answered the Touch Deprivation Scale (Punyanunt-Carter et al., 2009). The Touch Deprivation Scale, having undergone validation within a student sample, is a self-report questionnaire. This assessment comprises 14 items that prompt participants to evaluate the frequency of touch in their current lives and their present desire for tactile contact. Respondents rated each item on a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree", with higher ratings indicating a greater sense of touch deprivation. The items are categorised into three distinct aspects: 'Absence of touch', 'Longing for touch' and 'Use of sexual behaviour to be touched.' Mean scores for each of these subcategories are computed. Reliability analysis revealed internal consistency for the 'Longing for touch' subscale (Cronbachs's α = 0.8) and 'Use of sexual behaviour to be touched' (Cronbachs's α = -0.61), but not for the 'Absence of touch' subscale (Cronbachs's α = 0.10), 'Longing for touch' and 'Use of sexual behaviour to be touched' were included in subsequent analyses.

Touch Experience Questions. Participants were also asked about any history of negative experiences with interpersonal touch: "I recognise in my personal history the presence of negative/unpleasant experiences involving interpersonal touch", with response options "Yes", "No", and "Prefer not to answer". Additionally, participants were asked about conditions affecting their touch perception: "Do you live with any condition (physical or mental) that may change the way you sense or perceive tactile (neutral, pleasant, or painful) stimulation?" with response options "Yes" and a text box to specify, and "No". They were also invited to share any other relevant information that might influence their feelings about observing touch between others: “Is there anything else that you feel we haven’t covered about your own experience with touch that could impact how you feel about viewing other people touch?”, with a text box for responses. Responses to these questions were used to determine if any participants should be excluded from the analysis.

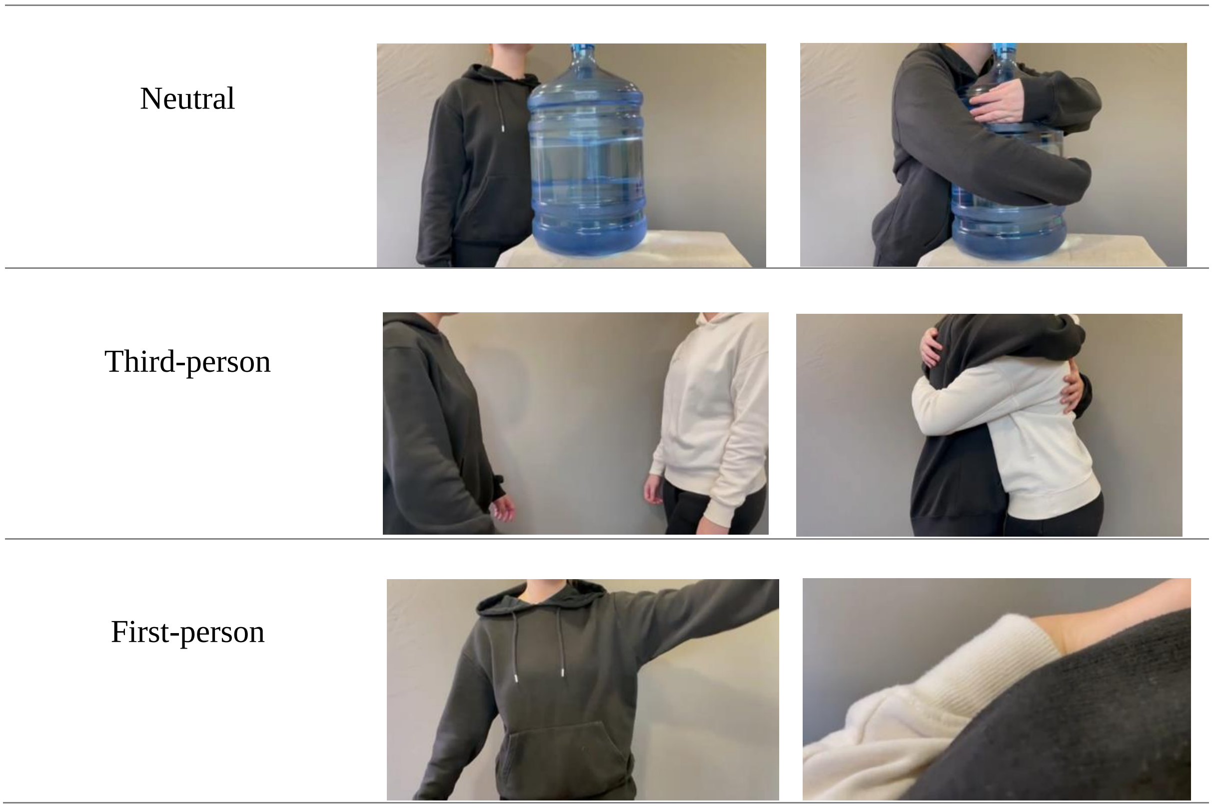
Biometric Sensors Used. Four types of physiological signals were recorded using iMotions: heart rate (HR), heart rate variability (HRV), galvanic skin response (GSR), pupil dilation (PD), along with a joy metric. HR, HRV, and GSR data were collected using Shimmer3 wearable Bluetooth sensors at a 512 Hz sampling rate. The Shimmer3 GSR+ device measured Electrodermal activity via Ag/AgCl electrodes attached to the index and middle fingers of the non-dominant hand, while the Shimmer3 ECG recorded HR and HRV using three electrodes placed on each clavicle and the upper left hip. Pupil dilation was tracked using a Tobii Pro Fusion eye tracker, calibrated with nine medium white points on a grey background. All physiological signals were recorded simultaneously and continuously throughout the study.

Joy levels were calculated using the Affectiva Affdex (version 5.1) software in iMotions, with analyses facial expressions to evaluate emotional states. This software, integrated with a Logitech HD Pro Webcam (C920) operating at a processing rate of 15 Hz, first detects faces using the Viola-Jones face detection algorithm (Viola & Jones, 2001) and then identifies 34 facial landmarks. It assigns scores from 0 to 100 for each facial action based on a model trained on a diverse dataset of manually coded facial images. These scores are used to calculate the likelihood of specific emotions, such as joy, by combining relevant facial expressions like cheek raising and smiling, in alignment with the Facial Action Coding System (FACS) (Friesen & Ekman, 1983). We focused on joy as it is a key emotion expected to be elicited by the videos, and it correlates with other affective measures, such as electromyography (EMG) responses (Kulke et al., 2020). EMG has been shown to reflect interpersonal touch responses (Pawling et al., 2017; Ree et al., 2019).

The HRV data were exported from iMotions as inter-beat intervals and calculated as the standard deviation of the normal-to-normal (NN) R-R intervals (SDNN) in milliseconds using Excel.

Video Stimuli. Six video stimuli were created for the purpose of this experiment in Psychopy (version 2021.2.2). These stimuli included two varying perspectives: first-person and third-person. Video durations were divided into two categories: 10 seconds and 30 seconds. 10 seconds videos used the first 10 seconds of the 30 second videos of each condition. Two actors were used for the filming of videos. Actor heads were out of frame to conceal physical attributes and sex, which could influence how the hugs were perceived. Actors wore baggy clothes to further hide sex difference. This was with the goal of portraying actors as (sex) neutral as possible. All video stimuli used a grey background screen. Among these stimuli, neutral videos portrayed actor one hugging a large water bottle (refer to Figure 4.1). This was used as neutral stimuli based on previous research showing that such, object-based touch is rated as neutrally valenced and pleasant (Lee Masson & Op de Beeck, 2018). For the first-person perspective, the video entailed actor one moving directly toward the camera, while actor two remained concealed behind it. This composition allowed only the arms and hands of actor two to be visible, creating the illusion that the viewer embodies actor two and the camera served as their vantage point. The third-person perspective videos showed both actors approach each other from opposing sides of the screen. The hug took centre stage, while the participant assumed the role of an observer witnessing a hug between two individuals.

Figure 4.1. *Vicarious hug video stimuli at 1 second (left) and 5 seconds (right)*



Stroop Task. A Psychopy task was constructed to induce mental stress using the Stroop task paradigm (Stroop, 1992), adapted from the version developed by Yanagisawa et al. (2010). This interaction rendition of the classic Stroop task was designed to display two rows of words on a computer screen. Participants were given the task of determining if the colour of the letters in the upper row matched the colour name printed in the lower row (see Figure 4.2). They indicated their response using the “yes” or “no” keys, designated as keys 1 and 2 on the top row on the keyboard, using their right hand (Yanagisawa et al., 2010). The “yes” key was positioned on the left and the “no” key on the right. 30 trials were presented in random order, with each of the three conditions (congruent, incongruent, neutral) comprising 10 trials (see Figure 4.2). The stimulus remained visible until a response was given or for a maximum of 2 seconds. In the neutral trials, the upper row displayed sequences of X’s (XXXX) in colours red, green, blue, or yellow, while the lower row contained congruent colour words (‘RED’, ‘GREEN’, ‘BLUE’, and ‘YELLOW’). In the incongruent condition, the colour name word was printed in a colour that did not match its semantic meaning.

All word stimuli were presented in English. To ensure sequential visual attention, the upper row appeared 100ms before the lower row (Schroeter et al., 2002). Equal probabilities of 50% were assigned to both “yes” and “no” responses. Immediate feedback was provided for correct or incorrect responses, displayed for one second. Correct answers triggered a screen displaying the message “Correct!” against a white background. Incorrect answers resulted in the message “Wrong!” accompanied by an angry face image from Tottenham et al. (2009) (refer to Figure 4.3) beneath the text. Failure to respond within the 2-second window was met with the message “Too slow!” alongside the same angry face image. After practice, participants received information regarding the percentage of correct responses and the statement “84% of people were faster than you”. The main Stroop task comprised 30 trials, each accompanied by feedback messages and a final feedback detailing the percentage of correct responses and the average reaction time. Prior to the main experiment, a practice session of seven trials was administered to ascertain correct response rates and reaction times for both the practice and experimental sessions.

Figure 4.2. *Instances of single Stroop task trials are shown for the neutral, congruent, and incongruent conditions*

Stroop test

Heart-rate variability (HRV), galvanic skin response (GSR), and Joy (Affectiva Affdex) measured

Neutral (10 trials)	**Congruent** (10 trials)	**Incongruent** (10 trials)
XXXX	GREEN	GREEN
GREEN	RED	BLUE

Figure 4.3. *Angry face image used in the feedback screens of incorrect or too slow Stroop task responses (Tottenham et al., 2009)*

Moving Clouds Video. Participants watched a video of moving clouds. This was taken from pexels.com (Refer to Figure 4.4). This video was looped three times to last 90 seconds.

Figure 4.4. *Moving clouds used in video form at the end of the Psychopy experiment to record recovery from the Stroop task*

Design

A between-participants design was chosen to prevent potential carryover effects that could arise if participants were exposed to multiple conditions. Additionally, repeating the Stroop task could lead to desensitisation, reducing its effectiveness as a stressor. Thus, each participant took part in one of 6 conditions: first-person perspective 10 seconds; first-person perspective 30 seconds; third-person perspective 10 seconds; third-person perspective 30 seconds; neutral 10 seconds; and neutral 30 seconds. The allocation of conditions was based on participant number, which were in ascending sequential order. This meant that the experimenter was not aware of which video condition the participant was allocated to.

The independent variables were perspective (first-person versus third-person versus neutral) and duration of exposure (10 seconds versus 30 seconds). The dependent variables were biosensor measurements (HR, HRV, GSR, PD, and joy).

Procedure

Participants commenced by thoroughly washing and drying their hands before familiarising themselves with the information sheet and consenting to participation. The Qualtrics survey followed. Subsequently, an elastic belt housing the ECG shimmer was secured around each participant's waist, with three ECG electrodes placed beneath the left and right clavicles, and on the upper left hip after alcohol cleaning. GSR sensor Velcro straps were positioned on the middle and index finger pads of the participants' non-dominant hand. Seating arrangements optimised eye tracker alignment and captured facial expressions within the camera frame. Participants underwent iMotions eye calibration, tracking a white dot on a grey screen across nine positions.

The experimental protocol commenced with an introduction screen, followed by instructions for the fixation cross resting period, during which participants viewed a grey screen with a black fixation cross at its centre for 90 seconds. Next, participants viewed hug interaction videos, each shown three times with three-second pauses, guided by personalised instructions based on allocated conditions. First-person perspective viewers were informed, "You will now watch a video of someone hugging you." Third-person viewers observed "a video of two people hugging," while neutral condition participants saw "video of someone hugging a water bottle." Videos were either 10 or 30 seconds long. After the final viewing, participants rated video pleasantness.

Next, a Stroop task introduction screen explained the colour-word test. Participants completed a practice session with seven trials, receiving immediate feedback for correct or incorrect responses lasting one second. Practice ended information on the percentage of correct responses and "84% of people were faster than you". The main Stroop task comprised 30 trials, each accompanied by feedback messages and a final feedback about the percentage they answered correctly and their average reaction time. Last, participants observed moving clouds for 90 seconds to gauge Stroop task recovery. The experiment concluded with a screen signalling its end, electrode removal, payment, and participant departure.

Statistical Analyses

All outcome variables (HR, HRV, GSR, PD, and joy) were log-transformed to approximate normal distributions. However, the log-transformed joy scores displayed a bimodal distribution across experiment stages (baseline, video viewing, Stroop task, and recovery), likely due to varying participant responses to the emotional stimuli. Despite this, the log-transformed joy scores were included as the dependent variable in our mixed effects models, as these models are robust against deviations from normality (Schielzeth et al., 2020). We confirmed the validity of our models by examining the residuals, which were normally distributed despite the bimodal nature of the log-transformed joy scores.

Outcome variables in were normalised against baseline levels, by subtracting baseline values from each experimental stage (video viewing, Stroop task, and recovery). Participants were excluded from analyses if they had missing data for the outcome variable, sociodemographic characteristic variables, or covariates, in each subset. Additionally, outliers were identified for pupil dilation using box-plot analysis (values 3 x IQR from above the third quartile or below the first quartile) and were removed (baseline: 1, video viewing: 2, Stroop task: 6, recovery: 4). Consequently, sample sizes varied across outcome variables (see Table 4.3).

Mixed effects models were used to investigate the relationship between video perspective (neutral, first-person, third-person), video length (10 seconds, 30 seconds), and experiment stage (video viewing, Stroop task, and recovery clouds) with each outcome variable. For mixed effects models, the reference video perspective was neutral, video length was 10 seconds, and the experiment stage was video viewing. Interaction terms were included between video perspective, video length, and experiment stage. Each model accounted for the nested structure of the data by incorporating a random intercept for each participant. Four models were created for each outcome variable, all incorporating fixed effects:

Model One: Included video perspective, video length, experiment stage, sociodemographic characteristics (age, sex, ethnicity, and education), and interaction terms between video perspective, video length, and experiment stage.

Model Two: Added pleasantness ratings for videos.

Model Three: Added the availability of a romantic partner.

Model Four: Added longing for touch, use of sexual behaviour to be touched, and social touch.

In the pupil dilation mixed-effects models, luminosity at each experiment stage was included as a covariate to ensure that differences in pupil size were not the result of brightness differences between experiment stages. To calculate the average luminosity for each stage, we used a recently developed mathematical model (Pansara et al., 2024). This model relies on a lookup table with 1330 entries that correspond to red-green-blue (RGB) intensity values of solid-colour images, as measured by a digital lux meter (LX1010BS; Dr.meter; [https://drmeter.com/]), Each pixel in an image is represented by three RGB intensity values (one for red, one for green, and one for blue), expressed as percentages of the maximum value. The model takes these RGB values as input, three integers ranging from 0 to 100 for each colour, and provides the corresponding luminosity value. This process was used to compute the overall luminosity for each experiment stage (see Table 4.1).

Table 4.1. *Luminosity levels (%) across different experiment stages and video conditions*

	Experiment stage								
	Baseline	Video condition						Stroop task	Recovery
		First-person		*Third-person*		*Neutral*			
		10s	**30s**	**10s**	**30s**	**10s**	**30s**		
Luminosity (%)	20.13	7.92	8.01	9.11	9.08	8.92	8.98	57	23.07

Note. Higher luminosity scores indicate more brightness during the experiment stage (0 – 100%)

Results

Participant characteristics

Table 4.2 shows the participant demographic characteristics across video (neutral, first-person, and third-person) and video length (10 seconds and 30 seconds) conditions.

Table 4.2. *Participant demographic characteristics and other covariates by condition combinations (video and video length)*

Video Type	Neutral		First-person		Third-person	
Video Length (seconds)	**10**	**30**	**10**	**30**	**10**	**30**
N	43	43	45	42	45	45

Age (Mean (SD))	41.3 (19.8)	36.7 (19.8)	41.2 (19.7)	42.1 (19.6)	38.8 (19.6)	38.5 (19.1)
Female (%)[a]	83.7	53.5	55.6	50	40	62.2
Ethnicity (%)						
White	58.1	46.5	53.3	42.9	44.4	46.7
Asian/Asian British or American	18.6	39.5	28.9	42.9	28.9	33.3
Black/African/Caribbean/Black British or American	18.6	9.30	15.6	14.3	22.2	15.6
Other	4.66	4.66	2.22	0.0	4.44	4.44
Highest Qualification (%)						
Bachelor's Degree or Higher	60.48	65.13	62.24	73.72	66.67	73.29
AS/A Level or Vocational Training	30.2	23.3	24.42	16.68	22.22	20.04
GCSEs or Below	9.31	11.64	13.33	9.52	11.11	6.66
Romantic Partner (%)[b]	76.7	62.8	73.3	57.1	71.1	60
Video Pleasantness (Mean)[c]	5.63	5.00	6.64	6.33	7.09	6.42
Longing for Touch (Mean)[d]	2.09	2.41	2.43	2.30	2.42	2.40
Use of Sexual Behaviour to be Touched (Mean)[e]	2.67	2.84	2.94	2.44	2.47	2.71
Total Social Touch (Mean)[f]	34.3	34.7	34.0	33.6	32.4	35.9

Note. These descriptive statistics were produced in the combined dataset before splitting this dataset into sub-datasets.

[a] Compared to males

[b] Compared to no romantic partner available

[c] Responded on an 8-point likert type scale (1 = extremely unpleasant, 5 = neutral, 9 = extremely pleasant), with higher scores indicating higher ratings of pleasantness

[d, e] Respondents rated each item on a 5-point Likert scale, ranging from “strongly disagree” to “strongly agree”, with higher ratings indicating a greater sense of longing for touch or use of sexual behaviour to be touched

[f] Respondents rated each item on a 5-point Likert scale, ranging from “not at all” to “extremely”. The total social touch score was calculated using the sum of the responses to all 20 questions. Lower scores indicate a stronger affinity for social touch

Mixed effects models

The following sections summarise the associations identified in the final models for each outcome variable, with the results presented in Tables 4.3 and 4.4.

Table 4.3. *The relationship between video type, video length, and heart rate, heart rate variability, galvanic skin response, pupil dilation, and joy*

Variable	**Model 1**[a] β (SE)	**Model 2**[b] β (SE)	**Model 3**[c] β (SE)	**Model 4**[d] β (SE)
Heart Rate (N = 231)				
Video (First-Person)	0.02 (0.03)	0.02 (0.03)	0.02 (0.03)	0.02 (0.03)
Video (Third-Person)	0.03 (0.03)	0.03 (0.03)	0.03 (0.03)	0.03 (0.03)
Video Length (30s)	0.02 (0.03)	0.02 (0.03)	0.02 (0.03)	0.02 (0.03)
Experiment Stage (Stroop)	**0.03 (0.02)***	**0.03 (0.02)***	**0.03 (0.02)***	**0.03 (0.02)***
Experiment Stage (Recovery)	-0.03 (0.02)	-0.03 (0.02)	-0.03 (0.02)	-0.03 (0.02)
Heart Rate Variability (HRV) (N = 216)				
Video (First-Person)	0.05 (0.12)	0.07 (0.12)	0.07 (0.12)	0.07 (0.12)
Video (Third-Person)	-0.11 (0.12)	-0.09 (0.12)	-0.09 (0.12)	-0.09 (0.12)
Video Length (30s)	0.05 (0.12)	0.03 (0.12)	0.03 (0.12)	0.04 (0.12)
Experiment Stage (Stroop)	0.11 (0.07)	0.11 (0.07)	0.11 (0.07)	0.11 (0.07)
Experiment Stage (Recovery)	**0.32 (0.07)*****	**0.32 (0.07)*****	**0.32 (0.07)*****	**0.32 (0.07)*****
Galvanic Skin Response (GSR) (N = 235)				
Video (First-Person)	0.06 (0.05)	0.05 (0.05)	0.05 (0.05)	0.05 (0.05)

Video (Third-Person)	0.002 (0.05)	-0.01 (0.05)	-0.01 (0.05)	-0.01 (0.05)
Video Length (30s)	-0.03 (0.05)	-0.03 (0.05)	-0.03 (0.05)	-0.03 (0.05)
Experiment Stage (Stroop)	**0.18 (0.03)*** **	**0.18 (0.03)*** **	**0.18 (0.03)*** **	**0.18 (0.03)*** **
Experiment Stage (Recovery)	**0.06 (0.03)***	**0.06 (0.03)***	**0.06 (0.03)***	**0.06 (0.03)***
Pupil Dilation (PD) (N = 225)				
Video (First-Person)	-0.31 (0.24)	-0.31 (0.24)	-0.31 (0.24)	-0.31 (0.24)
Video (Third-Person)	0.02 (0.04)	0.02 (0.04)	0.02 (0.04)	0.02 (0.04)
Video Length (30s)	**0.06 (0.02)** **	**0.06 (0.02)** **	**0.06 (0.02)** **	**0.06 (0.02)** **
Experiment Stage (Stroop)	12.13 (11.41)	12.13 (11.41)	12.13 (11.41)	12.13 (11.41)
Experiment Stage (Recovery)	3.50 (3.35)	3.50 (3.35)	3.50 (3.35)	3.50 (3.35)
Joy (N = 234)				
Video (First-Person)	-0.11 (0.73)	0.02 (0.73)	0.03 (0.74)	0.05 (0.74)
Video (Third-Person)	-1.06 (0.75)	-0.88 (0.76)	-0.87 (0.76)	-0.89 (0.76)
Video Length (30s)	-1.44 (0.75)	**-1.53 (0.75)***	**-1.50 (0.75)***	**-1.52 (0.76)***
Experiment Stage (Stroop)	**1.25 (0.59)***	**1.25 (0.59)***	**1.25 (0.59)***	**1.25 (0.59)***
Experiment Stage (Recovery)	-0.45 (0.59)	-0.44 (0.59)	-0.44 (0.59)	-0.44 (0.59)

Note. Mixed effects models examined the effects of video perspective (neutral, first-person, third-person), video length (10 seconds, 30 seconds), and experiment stage (video viewing, Stroop task, and recovery clouds) on each outcome variable. β(SE) indicates the regression coefficient (β) and its standard error (SE). Statistical significance is denoted by **p* < .05, ***p* < .01, ****p* < .001. Reference levels in these models are: neutral video perspective, video length of 10 seconds, and the video viewing stage. N denotes the sample size for each outcome variable. Estimates often change after 2 decimal places. The models build sequentially as follows:

[a] Model 1 (base model) adjusts for age, sex, ethnicity, education, and lux levels for PD.

[b] Model 2 adds video pleasantness ratings to Model 1.

[c] Model 3 adds romantic partner availability to Model 2.

[d] Model 4 adds longing for touch, use of sexual behaviour to be touched, and social touch to Model 3.

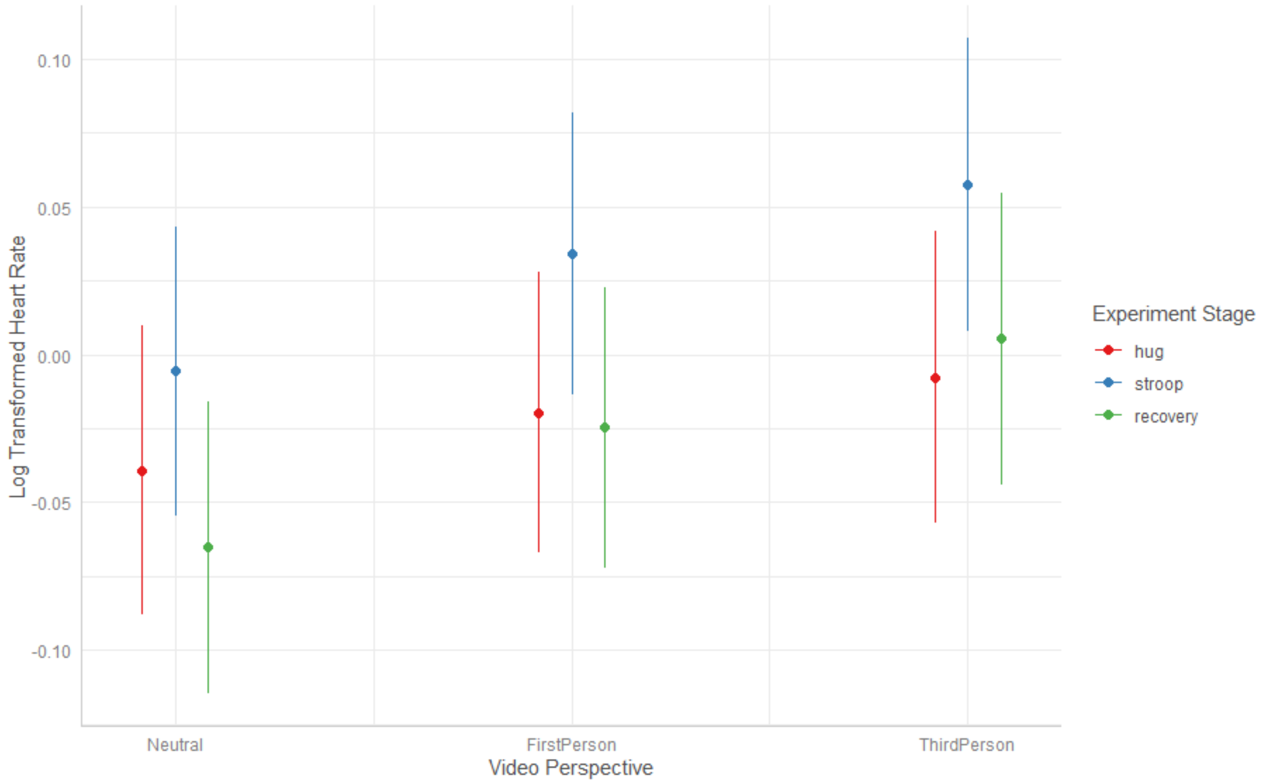
Table 4.4. *Interactions between Video Perspective, Video Length, and Experiment Stage, on each outcome measure in Models 4*

	Outcome Measure				
	β (SE)				
	HR (N = 231)	HRV (N = 216)	GSR (N = 235)	PD (N = 225)	Joy (N = 234)
First-person x 30s	0.01 (0.04)	-0.12 (0.17)	-0.02 (0.08)	-0.02 (0.03)	1.22 (1.06)
Third-person x 30s	-0.04 (0.04)	0.03 (0.17)	0.03 (0.08)	0.01 (0.02)	**2.73 (1.07)***
First-person x Stroop	0.02 (0.02)	-0.14 (0.10)	-0.02 (0.04)	0.32 (0.24)	-0.70 (0.83)
Third-person x Stroop	0.03 (0.02)	-0.02 (0.10)	0.04 (0.04)	-0.02 (0.04)	-0.01 (0.84)
First-person x recovery	0.02 (0.02)	-0.12 (0.10)	0.01 (0.04)	0.32 (0.24)	0.42 (0.83)
Third-person x recovery	0.04 (0.02)	-0.07 (0.10)	0.07 (0.04)	-0.02 (0.04)	1.00 (0.85)
30s x Stroop	0.02 (0.02)	-0.03 (0.10)	0.07 (0.04)	**-0.07 (0.02)*****	0.83 (0.85)
30s x recovery	0.03 (0.02)	-0.15 (0.10)	**0.12 (0.04)****	**-0.06 (0.01)*****	1.61 (0.85)

Note. β(SE) denotes the regression coefficient (β) and its standard error (SE) for each interaction term. Statistical significance is indicated as follows: **p* < .05, ***p* < .01, ****p* < .001. N denotes the sample size for these analyses.

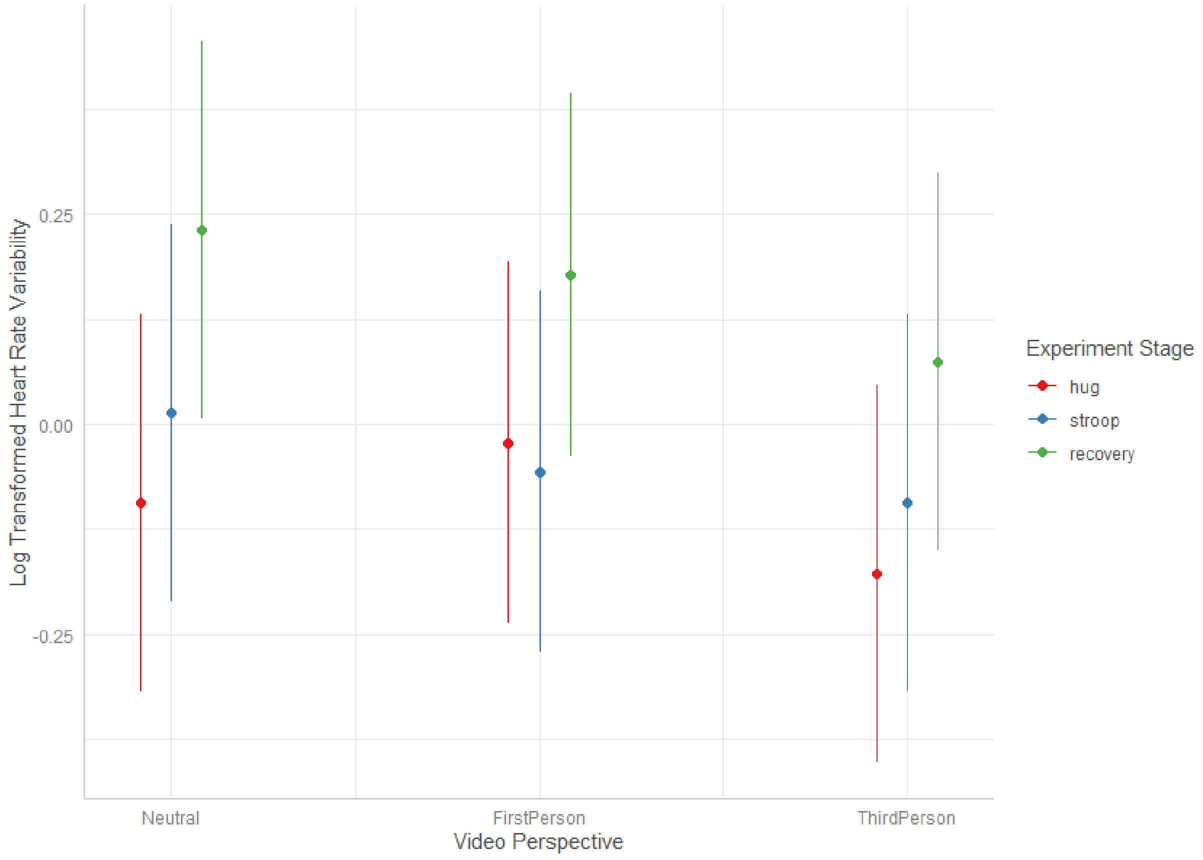
Heart Rate (HR). Neither video perspective (first-person: *β* = 0.02, *SE* = 0.03, *p* = .467; third-person: *β* = 0.03, *SE* = 0.03, *p* = .249) nor video length (30 seconds: *β* = 0.02, *SE* = 0.03, *p* = .515) varied by HR during video viewing compared to the neutral perspective and 10-second reference categories. In terms of experiment stage, HR was a significantly higher during the Stroop task experiment stage compared to the video viewing stage (*β* = 0.03, *SE* = 0.02, *p* = .038) (see Figure 4.5). There was no significant difference in HR during the recovery stage as compared to video viewing (*β* = -0.03, *SE* = 0.02, *p* = .112). No significant interactions were found between video perspective, video length, and experiment stage (refer to Table 4.4), suggesting that the increase in HR during the Stroop task was consistent across video and video length condition.

Figure 4.5. *Associations between Video Perspective and Experiment Stage on Log Transformed Heart Rate*



Heart Rate Variability (HRV). Neither video perspective (first-person: *β* = 0.07, *SE* = 0.12, *p* = .553; third-person: *β* = -0.09, *SE* = 0.12, *p* = .488) nor video length (30 seconds: *β* = 0.04, *SE* = 0.12, *p* = .736) had significant associations with HRV during video viewing compared to their respective reference categories (neutral perspective and 10 seconds). There was also no significant main effect of the experiment stage Stroop (*β* = 0.11, *SE* = 0.07, *p* = .120). However, a significant main effect was observed for the recovery stage (*β* = 0.32, *SE* = 0.07, *p* < .001), indicating that HRV was significantly higher during recovery than during video viewing for the reference condition (neutral perspective and 10 second duration). This increase in HRV during recovery typically reflects a return to a more relaxed state (see Figure 4.6). There were no other significant interactions (see Table 4.4).

Figure 4.6. *Associations between Video Perspective and Experiment Stage on Log Transformed Heart Rate Variability*



Galvanic Skin Response (GSR). The results show that neither video perspective (first-person: *β* = 0.05, *SE* = 0.05, *p* = .361; third-person: *β* = -0.01, *SE* = 0.05, *p* = .928) nor video length (30 seconds: *β* = -0.03, *SE* = 0.05, *p* = .630) had significant associations with GSR during video viewing compared to their respective reference categories (neutral perspective and 10 seconds) (see Table 4.3). However, GSR was significantly higher during the Stroop (*β* = 0.18, *SE* = 0.03, *p* < .001) and recovery stages (*β* = 0.06, *SE* = 0.03, *p* = .047) compared to the video viewing stage (see Figure 4.7). There was a significant interaction between video length (30 seconds) and the recovery stage (*β* = 0.12, *SE* = 0.04, *p* = .007) showing that GSR was higher during the recovery stage when neutral hug videos were longer (30 seconds) as compared to shorter (10 seconds) (see Figure 4.8). No other significant interactions were found (see Table 4.4).

Figure 4.7. Associations between Video Perspective and Experiment Stage on Log Transformed Galvanic Skin Response

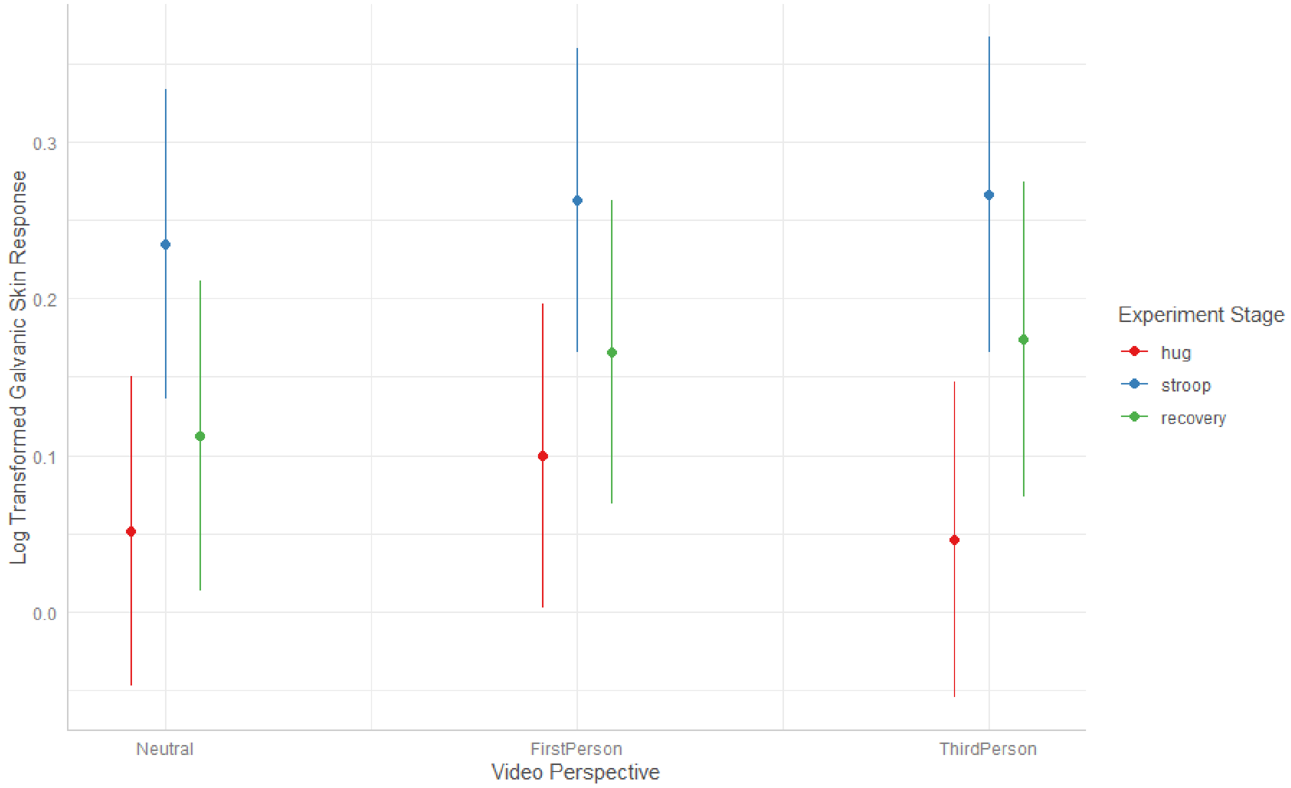
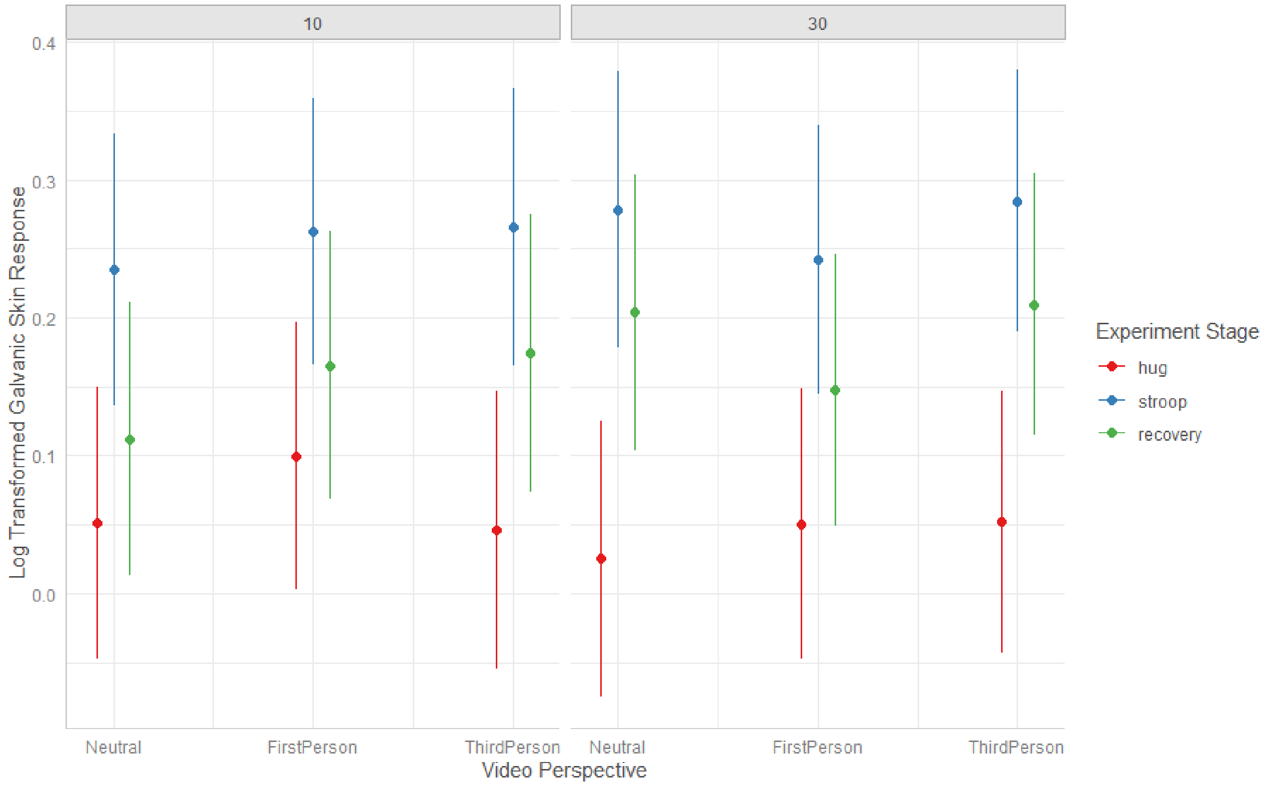
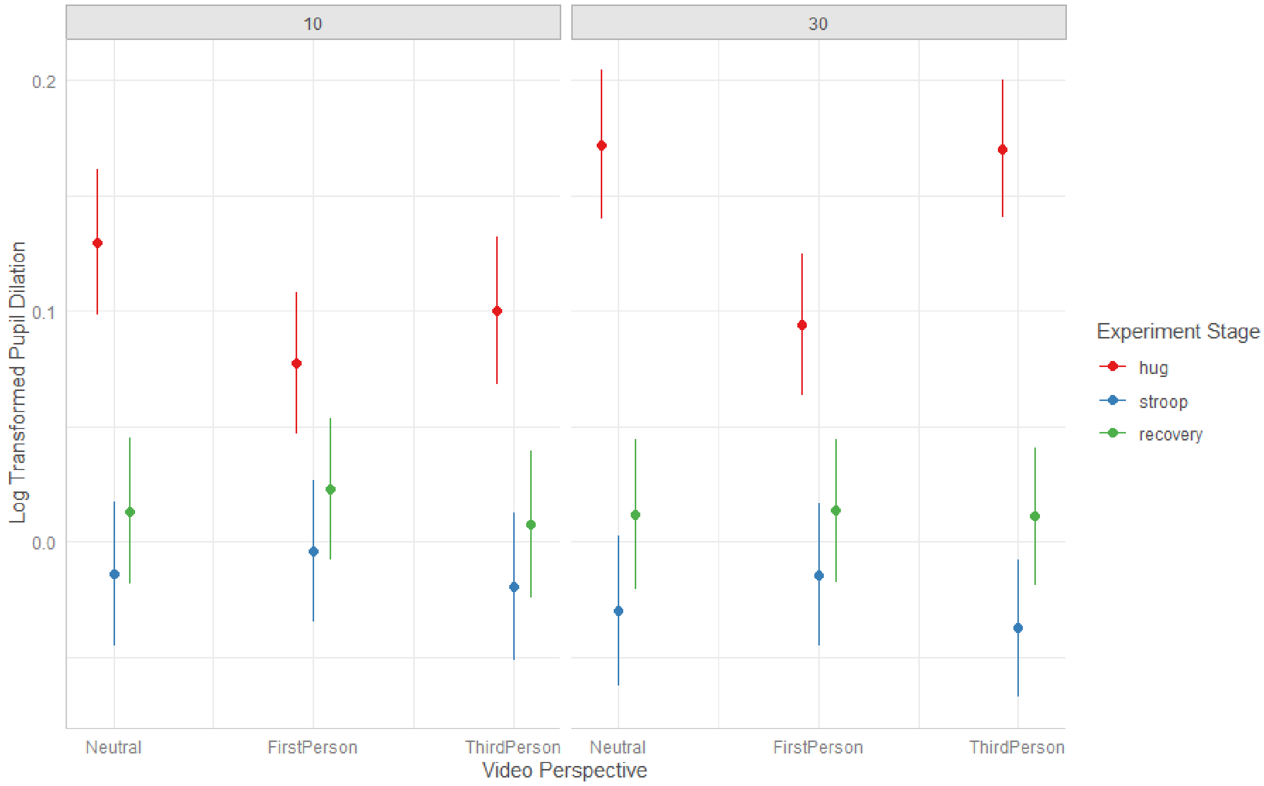


Figure 4.8. Associations between Video Perspective and Experiment Stage across Video Lengths on Log Transformed Galvanic Skin Response



Pupil Dilations (PD). The results indicate no statistically significant differences in PD during first-person (*β* = -0.31, *SE* = 0.24, *p* = .201) nor third-person (*β* = 0.02, *SE* = 0.04, *p* = .665) perspective videos compared to neutral videos. However, PD was significantly greater for longer (30 second) videos during neutral video viewing compared to shorter ones (10 seconds) (*β* = 0.06, *SE* = 0.02, *p* = .002) (refer to Figure 4.9). We found no significant differences in pupil size between experiment conditions, including the Stroop task (*β* = 12.13, *SE* = 11.41, *p* = .288) and the recovery stage (*β* = 3.50, *SE* = 3.35, *p* = .298) compared to the video watching stage. We observed significant interactions between video length and experiment stage, indicating that PD was significantly reduced during the Stroop task (*β* = -0.07, *SE* = 0.02, *p* < .001) and the recovery stage (*β* = -0.06, *SE* = 0.01, *p* < .001) in comparison to video viewing, for participants who watched longer (30 seconds) neutral videos as compared to shorter ones (10 seconds). This effect appears to be primarily driven by increased PD during the video viewing stage for 30 second neutral videos, rather than a decrease during the Stroop and recovery stages (see Figure 4.9).

Figure 4.9. *Associations between Video Perspective and Experiment Stage on Log Transformed Pupil Dilation across Video Length Group*



Joy. Neither the first-person perspective (*β* = 0.05, *SE* = 0.74, *p* = .942) nor the third-person perspective (*β* = -0.89, *SE* = 0.76, *p* = .243) significantly influenced joy compared to the neutral video. However, video length had a significant association with joy, with participants experiencing significantly less joy when watching 30-second neutral videos compared to 10-second neutral videos (*β* = -1.52, *SE* = 0.76, *p* = .045) (refer to Figure 4.10). Also, there was a significant increase in joy during the Stroop task (*β* = 1.25, *SE* = 0.59, *p* = .033) compared to the video viewing stage, but there was no significant difference during the recovery stage (*β* = -0.44, *SE* = 0.59, *p* = .454) relative to the video watching stage (see

Figure 4.11). Additionally, we saw a significant interaction between the third-person video perspective and video length, where longer third person videos (30 seconds) were associated with a significant increase in joy compared to neutral 30 second videos during video watching ($\beta = 2.73$, $SE = 1.07$, $p = .011$). Although this is largely driven by the reduction in joy during 30 second neutral videos rather than an increase in joy for 30 second third-person videos (see Figure 4.10).

Figure 4.10. *Associations between Video Perspective and Experiment Stage on Log Transformed Joy across Video Length Conditions*

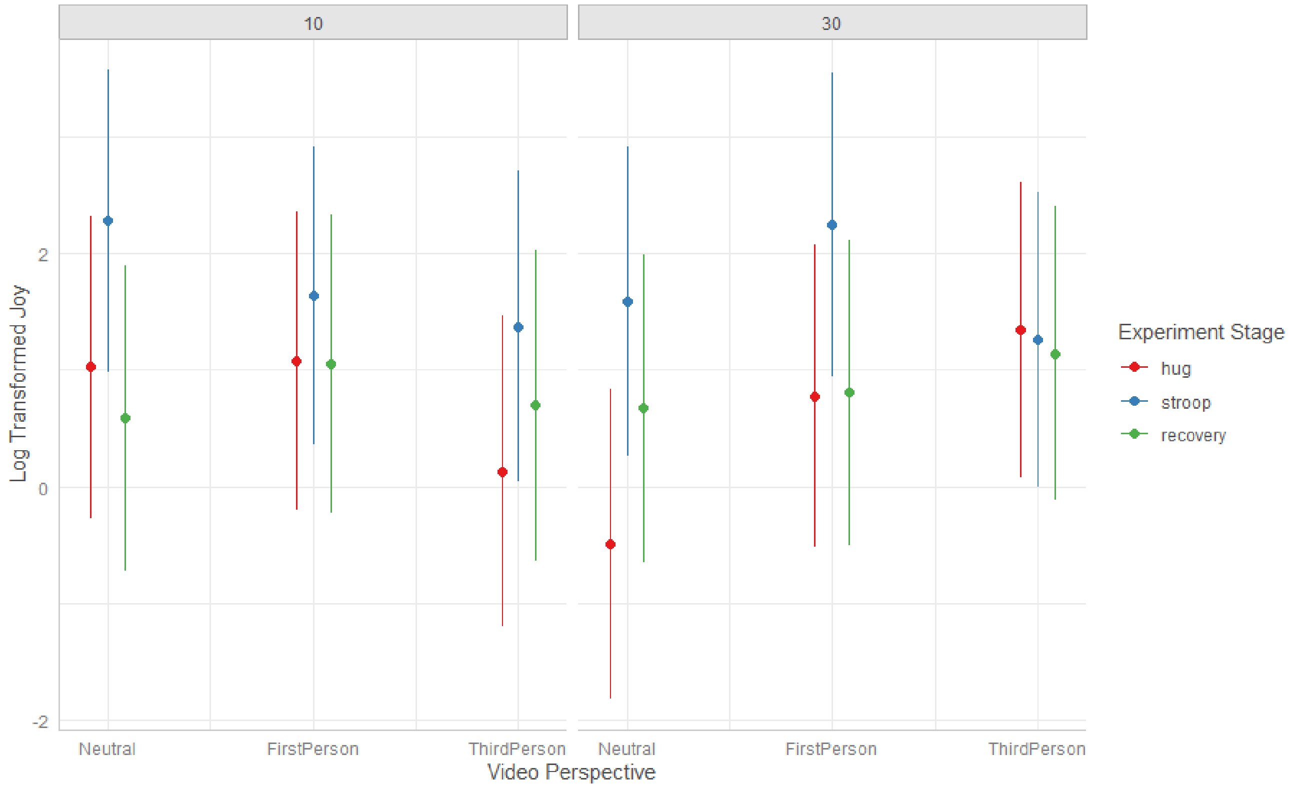
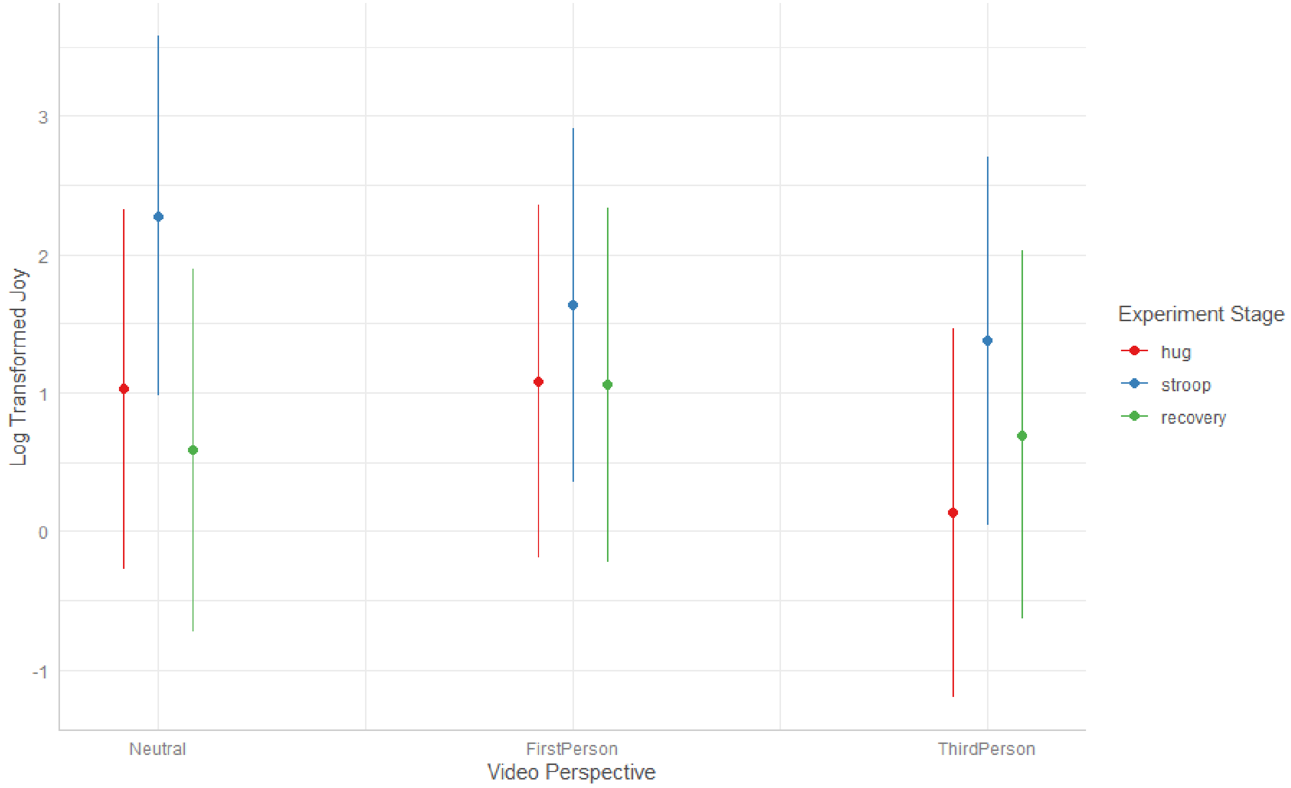


Figure 4.11. *Associations between Video Perspective and Experiment Stage on Log Transformed Joy*



Discussion

Hugging has been shown to provide emotional support (Grewen et al., 2003; Reis & Patrick, 1996) and act as a buffer against stress (Coan et al., 2006). Similarly, seeing others being touched activates brain regions that are typically involved in the direct experience of touch (Blakemore et al., 2005; Ebisch et al., 2008; Holle et al., 2013; Keysers et al., 2004; Kuehn et al., 2018; Kuehn et al., 2014; Kuehn et al., 2013; Masson et al., 2018). Research suggests that these vicarious experiences of touch can offer similar benefits to those of real physical touch (Björnsdotter & Olausson, 2011; Haggarty et al., 2021; Meijer et al., 2022), including perceived stress reduction (Kirsch et al., 2024). Despite this, the potential of vicarious hugging to evoke positive emotional responses and its stress-buffering effects are still underexplored. Additionally, little is known about the factors that might influence these vicarious experiences. The current study aimed to address these gaps by investigating whether vicarious hugs, differing in perspective (first-person vs. third-person) and duration (10 seconds vs. 30 seconds), could influence physiological responses during vicarious hug viewing, a stress-inducing task, and post-stress recovery.

Contrary to our expectations, we found no significant differences in HR, HRV, GSR, PD, or joy, between first-person, third-person, and neutral vicarious hugs. Previous studies have shown that vicarious painful touch can increase GSR (Fusaro et al., 2016), PD (Azevedo et al., 2013; Chiesa et al., 2015), and reduce HR (Fusaro et al., 2016). Similarly, vicarious CT-optimal touch has been linked to reduced frowning, increased smiling (Pawling et al., 2017; Ree et al., 2019), and decreased HR (Fusaro et al., 2016), indicating a positive affective response. Given the natural tendency to mirror others' sensations and emotions (Björnsdotter & Olausson, 2011; Keysers & Gazzola, 2009; Lamm et al., 2015), and the broader sensorimotor and socio-affective engagement in full-body stimuli like hugs (Schirmer & McGlone, 2019), we expected stronger physiological and emotional responses to interpersonal vicarious hugs, particularly those from a first person perspective. This perspective is thought to enhance self-referential processing and empathy (Fusaro et al., 2016; Saxe et al., 2006), unlike the neutral hug involving a water bottle, which lacks social and emotional significance (Lee Masson & Op de Beeck, 2018). Our finding of no significant physiological differences between vicarious hug conditions aligns with Fusaro et al (2016), who also observed no differential GSR response between pleasant and neutral vicarious stroking. Our results extends their conclusions by showing that this lack of distinction applies to a broader range of physiological measures beyond GSR, suggesting that vicarious hugs, like CT-optimal touch, may not inherently evoke distinct autonomic responses.

Our findings may be due to the limited effectiveness of the touch stimuli. The perception of touch as pleasant depends on sensory cues (Taylor-Clarke et al., 2002) and the recipient's motivational state (Triscoli et al., 2014). Without these factors, the anticipated pleasant response may not arise, with could explain the lack of distinct physiological changes for interpersonal vicarious hugs, especially those in the first-person perspective. We also predicted no change in HRV, consistent with previous research showing that gentle caressing maintains HRV, while tapping reduces it (Della Longa et al., 2021), suggested to be due to the non-affective nature of tapping. Contrary to expectations, we did not find decreased HRV in neutral hugs, even though water bottle hugs have previously been rated as neutrally valenced and pleasant (Lee Masson & Op de Beeck, 2018). First, this could suggest that physiological responses to real hugs are not mirrored in vicarious hugs. Second, our neutral condition still depicted a hug, although neutral vicarious hugs in this study were rated as most neutral on the pleasantness scale, so it is unlikely that they inadvertently introduced positive valence. Therefore, even though neutral hugs were the least pleasant compared to first-person and third-person vicarious hugs, they did not effect on physiology.

However, we observed significant differences in PD when comparing longer vicarious hug videos to shorter ones. PD increased during longer neutral videos, with similar increases seen for both first-person and third-person perspectives, suggesting that video length consistently influenced PD across all conditions. PD is influenced by autonomic nervous system activity; specifically, increased sympathetic activation causes dilation through the dilator muscle, while reduced parasympathetic activity decreases constriction of the sphincter muscle (Bradley et al., 2008; Steinhauer et al., 2004). Emotional stimuli typically trigger PD as a marker of autonomic arousal (Bradley et al., 2008; Partala & Surakka, 2003; Steinhauer et al., 2004), with both positive and negative stimuli capable of eliciting similar pupillary responses. Contrary to our hypothesis, first-person and third-person videos did not elicit larger pupil responses compared to neutral videos. This suggests that watching a longer hug video may induce emotional arousal regardless of perspective, or interpersonal context, which differs from previous findings that suggest observed body parts (hands, arms, and feet) from the perspective of the viewer increased somatosensory cortex activation compared to observed body parts from which the viewer's own body would be inaccessible (Saxe et al., 2006). Furthermore, our findings are not in line with findings of earlier event-related potentials (ERPs) in response to viewing a pencil touch the observers own face compared to viewing touch on another person's face (Adler et al., 2016). In this study, video duration was the primary factor driving autonomic arousal, aligning with research showing longer hugs are rated as more pleasant (Dueren et al., 2021). Once more, all videos featured a hug, limiting our ability to determine whether the observed physiological effects were specific to hugs or would generalise to non-hugging videos. While pleasantness ratings varied across the vicarious hug videos, all elicited similar levels of PD, suggesting no direct correspondence between PD and subjective ratings of pleasantness.

Despite increased PD indicating heightened emotional arousal, no corresponding significant changes were observed in GSR or HR. GSR primarily reflects sympathetic nervous system activity through sweat gland response (Sugenoya et al., 1990), while HR is influenced by both sympathetic and parasympathetic inputs but is largely governed by parasympathetic tone (Akselrod et al., 1981; Boucsein, 2012; Craft & Schwartz, 1995; Mendelowitz, 1999). PD is a rapid and sensitive measure of arousal, whereas GSR and HR reflect slower, more generalised autonomic changes. This suggests that pupil size may be more sensitive to subtle emotional changes caused by longer exposure to vicarious videos, while GSR and HR may not detect these responses as effectively. Wang et al. (2018) also found that pupil size correlates with GSR before emotional stimuli, but this relationship tends to diminish after stimulus presentation, possibly due to the intensity of the emotional stimuli. The emotional intensity of the vicarious hug videos may not have been sufficient to elicit significant GSR and HR changes, despite indicating some level of arousal through PD. This underscores the need for future research to explore how varying emotional intensities in vicarious touch stimuli influence different autonomic responses, providing a more comprehensive understanding of emotional arousal.

Furthermore, our results showed higher joy during longer third-person hugs compared to longer neutral hugs, with no significant difference between longer neutral hugs and first-person hugs. This effect was mainly driven by a significant decrease in joy during the longer neutral videos rather than an increase in joy during the third-person condition. This suggests that third-person hugs may have been perceived as less negative, possibly because the third-person perspective engaged viewers' empathy and sense of social connection more effectively. In contrast, the first-person and neutral videos lacked the same interpersonal engagement, which might have led to a decline in emotional appeal over time, contributing to lower joy levels. Prior research indicates that object-based touch, like the neutral hug scenario, is generally rated as less pleasant than interpersonal touch (Lee Masson & Op de Beeck, 2018). Additionally, the absence of a visible hugger's face or clear intention in the first-person video could have reduced its emotional impact, creating a sense of discomfort or mismatch with viewers' expectations (Gazzola et al., 2012). These findings imply that first-person perspective hugs may not evoke the same self-related experiences as first-person CT-optimal touch, such as forearm stroking. The forearm may be more easily perceived as one's own body, while hugs are more complex and encompass multiple body regions, making it harder for the brain to process the touch as self-referential (Adler & Gillmeister, 2019; Cardini et al., 2011; Saxe et al., 2006).

The Stroop task successfully induced stress, as indicated by increased HR and GSR, consistent with previous research on stress responses to cognitive challenges (Fink et al., 2014; Healey & Picard, 2000; Lundberg et al., 1994; Pehlivanoğlu et al., 2005; Renaud & Blondin, 1997; Zhai & Barreto, 2008). Contrary to our expectations, neither first-person nor third-person hug videos buffered stress more effectively than the neutral videos, despite being perceived as more pleasant than neutral hugs. We did find that participants who viewed longer videos exhibited decreased PD during the Stroop task. Typically, PD increases under stress due to sympathetic nervous system activation, while smaller PD indicates parasympathetic dominance and relaxation (Andreassi, 2010; Granholm & Steinhauer, 2004; Steinhauer et al., 2004; Stern et al., 2001; Verney et al., 2004). However, this reduction is likely due to the increased PD observed during longer video viewing rather than a stress-buffering effect, particularly considering the absence of significant changes in HR and GSR. Thus, although subjective reductions to stress have been reported in response to vicarious human-to-human and human-to-pet touch (Kirsch et al., 2024), the physiological effects of more pleasant and self-related vicarious hugs may not manifest similarly.

Additionally, we found that participants displayed more joy during the Stroop task than during video viewing. The Stroop task, while challenging, requires focused attention and self-regulation, and for some participants, successfully navigating this challenge may evoke a sense of accomplishment or positive emotion, reflected as increased joy in facial expressions (Folkman & Moskowitz, 2000). This form of "good stress," or eustress, can enhance feelings of satisfaction and joy, particularly when the task is seen as an opportunity for mastery (LePine et al., 2005). Positive affect often arises when individuals appraise the resolution of a stressful encounter as successful, leading to emotions such as happiness or pride (Folkman & Lazarus, 1985). In contrast, watching hug videos is a passive activity that may not elicit the same level of emotional engagement. However, it is also possible that the observed differences in joy were influenced by measurement limitations. Prior research has shown that the Affectiva Affdex system tends to perform better with clear, static expressions compared to more natural, dynamic facial movements (Magdin et al., 2019). This potential measurement issue is further highlighted by our findings of increased HR and GSR during the Stroop task, indicating heightened stress levels, unless these measures also indicated eustress.

During post-stress recovery, markers of relaxation included significantly higher HRV when participants watched a video of moving clouds compared to hug videos, indicating a return to a calmer state. HRV, which measured in this study using the standard deviation of normal-to-normal (SDNN) R-R intervals, reflects the body's ability to recover from stress, with higher values indicating more effective stress adaptation (Immanuel et al., 2023). Additionally, PD during recovery was reduced for participants who watched longer videos, regardless of video perspective or interpersonal factors. This effect, also observed during the Stroop task, is likely due to prior increased PD during longer video viewing, rather than indicating a stress-buffering effect of longer videos. In contrast, GSR remained elevated during recovery compared to its level during hug video viewing, similar to the Stroop task, indicating incomplete return to pre-stress arousal. This suggests that while GSR effectively measures stress, its response is more delayed compared to HR, which returned to baseline during recovery. Higher GSR levels were also observed for participants who watched longer neutral hug videos, possibly reflecting delayed physiological recovery likely due to sustained emotional engagement.

This study employed four models, after the first model, each incorporated additional covariates; however, these covariates did not alter the outcomes. Model one controlled for sociodemographic characteristics (age, sex, ethnicity, and education). Model two introduced pleasantness ratings for the videos, while model three added the availability of a romantic partner. Finally, model four included longing for touch, use of sexual behaviour to be touched, and social touch. The consistency of the primary relationships observed across all models suggests that the outcomes were robust and largely unaffected by these additional factors. This indicates that the associations between vicarious hug videos and physiological outcomes are resilient to variations in the covariates, and that the covariates themselves likely did not significantly influence the results.

In this study, screen brightness was consistently set at 75% across all participants to standardise the visual environment. We also controlled for luminosity levels across different experimental stages in the mixed effects models. However, future studies should aim to directly measure the impact of luminosity on pupil size to ensure that it does confound the assessment of emotional responses. The model used to measure luminosity of the experiment stages in this study was based on unlit environments, unlike our setup in a lit room (Pansara et al., 2024). Since pupil size varies with lighting conditions, measuring luminosity in the specific experimental environment would be more appropriate. Additionally, controlling for luminosity as a covariate in a mixed effects model is challenging because the relationship between luminosity and pupil size is not linear (Zhang et al., 2019). Although, researchers typically address the influence of luminosity on pupil size by using baseline data or controlling lighting conditions (Aracena et al., 2015; Bradley et al., 2008), there is no validated method to completely remove the influence of luminosity on pupil size related to emotional arousal. While our approach has limitations, there is no consensus to date on the correct approach to take to control for luminosity.

Furthermore, this study utilised multiple physiological measures simultaneously using iMotions, including HR, HRV, GSR, PD, and joy measured using Affectiva Affdex. However, the protocol may not have optimised these measures. For example, allowing longer measurement durations could lead to more consistent responses across all markers, as GSR may have stabilised during the recovery stage, similar to HR. Optimal GSR measurement typically requires participants to rest for at least five to ten minutes before recording to establish a stable baseline (Boucsein, 2012), but this study allowed only 90 seconds. While 10 to 15 seconds is often adequate to capture the full emotional response cycle with GSR

(Critchley, 2002), responses to complex stimuli, such as videos or continuous interactions, may require longer to develop. Skin conductance may be categorised into phasic skin conductance response (SCR) and tonic skin conductance level (SCL), which indicate rapid and slower shifts in autonomic arousal, respectively (Boucsein, 2012). Analysing SCR and SCL separately allows researchers to distinguish whether physiological changes arise from specific stimuli or overall arousal levels (Boucsein, 2012). However, this study focused primarily on general arousal rather than the nuances of emotional responses. Nonetheless, future studies should examine the difference in SCR and SCL in response to vicarious touch. Additionally, the Stroop task may not have been sufficiently long to affect parasympathetic changes; longer recordings, sometimes up to 24 hours, are generally more reliable for this purpose (Bansal et al., 2009; Kim et al., 2018; Shaffer & Ginsberg, 2017). This limitation could explain the lack of significant increases in HRV during vicarious touch, contrasting with findings from Triscoli, Croy, Steudte-Schmiedgen, et al. (2017), who observed significant HRV changes with continuous real stroking lasting an average of 35 minutes. Future research should aim to optimise the measurement of each physiological marker, though this may require separate studies. However, this approach has its drawbacks, as isolated measurements may not provide a comprehensive understanding. Employing multiple measures could enhance the interpretation of arousal valence, clarifying whether it is positive or negative. While the simultaneous use of various measures is theoretically beneficial, its practical implementation can be challenging.

The emotional experience of touch depends heavily on its alignment with the recipient’s desires (Sailer & Leknes, 2022). The meaning of touch is shaped by factors including the body part involved, the touch initiator, the relationship between individuals, the touch’s purpose, accompanying verbal messages, and the recipient’s perception (Jones & Yarbrough, 1985). Simply showing participants a hug may not have provided sufficient context to elicit positive emotions, as the lack of information about the hug's purpose can affect its perceived positivity and meaning (Morrison, 2023; Sailer & Leknes, 2022). Additionally, participants may perceive touch as negative if they are not receptive to being touched, which could affect their response to first-person perspective hugs. In these videos, the giver's face was not visible, which might have led participants to imagine the touch coming from an unknown person, especially because a specific person to imagine was not stated. Touch imagined with a partner tends to be more positively perceived than touch from a stranger (Krahé et al., 2023). Furthermore, the first-person videos featured an actor initiating the hug, whereas mutually initiated touches are generally viewed more favourably (Sailer et al., 2024). These insights, while primarily related to real touch, may be relevant for vicarious touch as well. Future research should carefully consider the context in which touches are shown to participants, as this context could significantly influence how the touch is perceived, especially in first-person perspective scenarios.

This study explored the effects of vicarious hugs, presented in first-person and third-person perspectives, on physiological and emotional responses, and in response to a stress-inducing task. Contrary to expectations, the results revealed no significant differences in HR, HRV, GSR, PD, or joy, between the vicarious hug conditions and the neutral control. This lack of distinct physiological responses suggests that vicarious hugs, despite their potential for positive emotional engagement, may not inherently elicit the anticipated stress-buffering effects. The findings highlight the complexity of emotional experiences related to touch and underscore the importance of contextual factors, such as perceived intimacy of the touch and the viewer's emotional state. Notably, increased PD during longer video presentations suggests that video duration, rather than the nature of the touch, may be a more significant factor in eliciting emotional arousal. While longer viewing times appeared to enhance emotional engagement, this did not translate into significant changes in GSR or HR, indicating that these measures may not fully capture subtle emotional responses. Additionally, the study reveals the necessity of considering individual differences in how touch is perceived, particularly in first-person scenarios where the absence of visible touch initiators may affect participants' emotional responses. Future research should further investigate the nuanced effects of vicarious touch, exploring how varying emotional contexts and participant characteristics influence both subjective and physiological responses. By refining methodologies and expanding our understanding of vicarious touch, we can better comprehend its role in emotional well-being and stress resilience.

5. Electrophysiological Correlates of Touch in Older Adults: EEG and ECG Responses to Close, Stranger, and Vicarious Interactions

Introduction

Interpersonal touch is a fundamental aspect of human interaction, crucial for fostering social bonds and communication (Cekaite & Goodwin, 2021). Insufficient touch in adulthood is associated with heightened anxiety, depression, reduced well-being, and loneliness (Debrot et al., 2021; Floyd, 2014; Heatley Tejada et al., 2020; Stein & Sanfilipo, 1985). Conversely, interpersonal touch enhances well-being (for a review, see Jakubiak & Feeney, 2017), conveys positive affect (Pawling et al., 2017; Perini et al., 2015), promotes physiological relaxation (Edwards et al., 2018; Lindgren et al., 2010; Triscoli, Croy, Olausson, et al., 2017; Triscoli, Croy, Steudte-Schmiedgen, et al., 2017), and improves stress responses (Morrison, 2016b).

Stress is the body's physiological response to environmental demands (Sapolsky, 2021). Sensory systems detect these stressors, sending signals to the brain for evaluation (Pérez-Valenzuela et al., 2019). When an organism's integrity is threatened, structures like the amygdala and hypothalamus trigger the stress response by activating the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis (McEwen & Akil, 2020). This leads to adrenaline and cortisol release, increasing heart rate (HR) and blood sugar to help the body cope with stress (Herman et al., 2020). While moderate stress can be adaptive (Arnsten, 2009), managing excessive stress is vital for health. Sensory input, particularly touch, plays a key role in stress modulation, possibly through increased oxytocin release and vagus nerve activity, which together reduce autonomic arousal and enhance relaxation (Carter, 1998; Eckstein et al., 2020; Ferrell-Torry & Glick, 1993; Kreuder et al., 2019; Morrison, 2016b).

Experimental studies consistently show that various types of partner touch protect against stress. Before a stressor, partner neck and shoulder massages lower cortisol levels and HR in women (Ditzen et al., 2007), and pre-stress handholding and hugs reduce blood pressure and HR (Grewen et al., 2003). Even imagined partner touch support prior to stressful task buffered pain and subjective stress responses (Jakubiak & Feeney, 2016, 2019). During stress, partner handholding reduces neural responses to threats (Coan et al., 2006) while stroking reduces HR (Triscoli, Croy, Olausson, et al., 2017). Post-stress, partner handholding boosts heart rate variability (HRV) (Conradi et al., 2020), and speeds cortisol recovery (Ditzen et al., 2019; Schneider et al., 2023). Frequent partner touch is also associated with benefits, such as higher baseline oxytocin and reduced blood pressure responses (Light et al., 2005), as well as lower subjective stress and higher positive mood the following day (Burleson et al., 2007). Greater hugging over 14 days led to faster recovery from the common cold (Cohen et al., 2015). Four weeks of increased touch raised oxytocin and lowered cortisol in both partners, with reduced blood pressure in men (Holt-Lunstad et al., 2008). More frequent kissing over six weeks resulted in lower perceived stress, greater relationship satisfaction, and improved cholesterol levels (Floyd et al., 2009). Pregnant women receiving massages over 16 weeks showed higher dopamine and serotonin, with reduced cortisol and norepinephrine (Field et al., 2004). Thus, various types of partner touch, before, during, and after stress are associated with enhanced physiological, emotional, and subjective stress responses, with similar benefits seen even from imagined touch. Additionally, frequent everyday touch with partners is associated with positive health outcomes. However, most research focuses on partner touch and younger adults with ample touch access.

Moreover, direct comparisons of different types of touch are limited. Touch types differ in terms of body location, social context, and emotional response (Schirmer et al., 2021). Research indicates that people experience handshakes more frequently than desired, whereas hugs and stroking are sought more often than received (Beßler et al., 2020). Although handholding is generally preferred over stroking for emotion regulation in intense situations (Sened et al., 2023), some studies report minimal differences in their effects (Cruciani et al., 2021). For instance, Reddan and colleagues (2020) found that both handholding and stroking from a partner provided similar levels of pain relief from thermal stimulation, although handholding was slightly more effective. Despite the known physiological benefits of various touch types, such as hugging and stroking, direct comparison are scarce. Furthermore, different types of touch may engage distinct neural processing mechanisms (Saarinen et al., 2021). Notably, the neural oscillatory patterns associated with these touch types remain largely unexplored, suggesting a significant area for future research.

To understand these differences, it is essential to examine the skin's nerve network, which transmits sensory signals that support both discriminative and emotional functions. A-beta (Aβ) fibres rapidly convey spatial and temporal details about touch, while unmyelinated C-tactile (CT) fibres are specialised for slow, gentle stroking, associated with comfort (Löken et al., 2009; McGlone et al., 2014; Olausson et al., 2002; Olausson et al., 2010; Olausson et al., 2008). CT-fibres optimally respond to specific speeds (1-10 cm/s) and skin temperatures, providing the neurobiological basis for soothing touch (Löken et al., 2009; Olausson et al., 2002; Olausson et al., 2010; Olausson et al., 2008). While Aβ-fibres target the primary somatosensory cortex, CT-optimal touch activates brain areas involved in emotional processing, such as the insular and orbitofrontal cortex (Gordon et al., 2013; McGlone et al., 2007; Morrison et al., 2010). Affective touch, including stroking and holding, engages both Aβ- and CT-fibres, with signals integrated at the dorsal horn and relayed to brain regions associated with emotional states (e.g., insular, orbitofrontal, and superior temporal cortices) (Abraira & Ginty, 2013; Davidovic et al., 2016; Gordon et al., 2013; McGlone et al., 2012;

Olausson et al., 2002). CT-optimal touch is consistently rated as more pleasant than other touch types (Pawling et al., 2017). However, moderate or deep pressure touch also elicit positive emotional responses; for example, moderate massage showed greater reduction in HR, subjective stress, and increases in relaxation as shown by EEG changes (higher delta, lower alpha and beta) and increased positive affect (left frontal EEG activation) compared to light massage or vibration (Diego et al., 2004). Similarly, deep pressure from an oscillating compression sleeve was subjectively pleasant and calming, and activated brain regions similar to those responsive to CT-optimal stroking (Case et al., 2021).

Although the density of tactile fibres decreases with age (Chang et al., 2004; Gøransson et al., 2004), CT-fibres remain relatively resilient (McIntyre et al., 2021). Nevertheless, older adults may have different touch experiences compared to younger adults due to smaller social networks (Pedell et al., 2010), higher rates of living alone (ONS., 2021), and increased loneliness (Pino et al., 2014; Scharf & de Jong Gierveld, 2008). Larger households can reduce loneliness more effectively in older adults than in midlife adults (Victor & Yang, 2012), yet many older adults live alone and may face greater risk of social isolation (ONS, 2021; Pino et al., 2014), and possibly touch deprivation. While those feeling touch-deprived rate CT-optimal stroking as less pleasant despite similar attitudes toward touch (Sailer & Ackerley, 2019), older adults generally find gentle touch more pleasant and emotionally rewarding than younger individuals (Guest et al., 2014; Ishikura et al., 2024). This greater appreciation may result from reduced touch frequency, although this remains speculative (Sehlstedt et al., 2016), and requires further examination.

Research on touch and health outcomes in older adults often focuses on nursing and clinical populations. For example, light touch on the forearm enhances nonverbal communication in confused older adults (Langland & Panicucci, 1982) and reduces depressive symptoms (Buschmann et al., 1999). In dementia patients, touch therapies like massage help alleviate depression and agitation behaviours (Watt et al., 2021; Watt et al., 2019). In non-clinical settings, robotic faster (8.5 cm/s) back stroking has shown more positive subjective valence and increased arousal than slower stroking (2.6 cm/s), although faster stroking showed weaker corrugator electromyography (EMG) activity and stronger skin conductance response than slower stroking in both younger and older adults (Ishikura et al., 2024). Furthermore, longitudinal data from the National Social Life, Health and Aging Project (NSHAP) indicates that touch in older adults is associated with lower blood pressure, reduced HR (Lee & Cichy, 2020), decreased inflammation (Thomas & Kim, 2021), and lower neuroendocrine load (Navyte et al., 2024). However, the NSHAP findings rely on retrospective touch reports over the past 12 months, raising concerns about the reliability of long-term self-reports. More immediate assessments of touch frequency are needed to validate these outcomes and the validity of long-term self-reports of touch frequency.

Furthermore, research on touch predominantly focuses on romantic partners, with limited studies examining touch from individuals of varying closeness. Existing findings on stranger touch are mixed. For instance, a hug from a stranger can lower cortisol levels (Dreisoerner et al., 2021), but it can also increase physiological arousal in stressful situations (Debrot et al., 2024). Similarly, while touch from an experimenter lowered HR, it also raised skin conductance, suggesting both calming and arousing effects (Vrana & Rollock, 1998). This response resembles Autonomous Sensory Meridian Response (ASMR), characterised by pleasant tingling sensations triggered by sights and sounds and associated with reduced HR, increased GSR, and enhanced social connectedness (Poerio et al., 2018). Comparative studies show that partner touch often reduces stress more effectively than stranger touch (Coan et al., 2017; Coan et al., 2006) and is perceived as more pleasant and pain-relieving (Kreuder et al., 2017; Kreuder et al., 2019). However, a recent systematic review and meta-analysis found that touch interventions could be delivered effectively by both close individuals (such as partners, family, or friends) and by strangers (such as healthcare professionals), with no significant impact of emotional closeness on outcomes. Likewise, no differences in mental and physical health benefits were observed based on the emotional closeness of the touch provider (Packheiser et al., 2024b). Additionally, touch frequency and need are generally higher with partners than with strangers (Beßler et al., 2020). Differences also exist in acceptable touch areas: strangers are usually restricted to touching the hands, while close acquaintances or partners can touch more intimate areas like the head and upper torso (Suvilehto et al., 2015; Suvilehto et al., 2019). However, CT-fibres stimulation is consistently associated with positive affect, regardless of whether the stroking is delivered from a close individual (Triscoli, Croy, Olausson, et al., 2017) or a stranger (Kirsch et al., 2018). Given the mixed findings, it remains uncertain which of these patterns applies to older adults, who may experience touch differently depending on the emotional closeness of the person providing it.

An emerging area of interest is vicarious touch, defined as the perception of touch through visual feedback (Haans & IJsselsteijn, 2009). Research indicates that observing touch activates brain regions and emotional responses similar to those involved in directly experiencing touch (Björnsdotter & Olausson, 2011; Bufalari et al., 2007; Haggarty et al., 2021; Keysers et al., 2004; Lloyd et al., 2004; Pisoni et al., 2018; Rigato, Bremner, et al., 2019). This phenomenon aligns with Simulation Theory, which proposes that we mentally simulate others’ experiences to understand their states (Gallese & Goldman, 1998; Goldman et al., 2006). (Björnsdotter & Olausson, 2011; Bufalari et al., 2007; Forster & Abad-Hernando, 2024; Haggarty et al., 2021; Pisoni et al., 2018; Rigato, Bremner, et al., 2019; Smit et al., 2023). For example, observing human-human or human-pet hugs can elicit subjective calm and pleasant emotions (Kirsch et al., 2024). However, vicarious touch perception may decline with age (for a review, see Gillmeister et al., 2017). Age-related changes in brain structure, linked to reduced tactile sensitivity and sensorimotor coordination, could weaken the neural representations of observed touch (Kalisch et al., 2009). Additionally, older adults' diminished emotion perception may impair their empathetic responses to vicarious touch (Ruffman et al., 2008; Yang & Banissy, 2016). While vicarious touch offers potential benefits similar to direct touch, its effectiveness may decrease with age, warranting further investigation. Additionally, vicarious touch could offer a greater benefit in older adults, similar to real touch, which older adults find more pleasant (Guest et al., 2014; Ishikura et al., 2024).

Despite increasing interest in the role of touch, its study within social neuroscience remains limited. Electroencephalogram (EEG) oscillations, categorised by frequency bands, delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (30-80 Hz), play distinct roles in sensory and emotional processing, although their exact functions are still debated (Knyazev et al., 2006). Von Mohr et al (2018) suggested that EEG oscillations in the theta, beta, and alpha bands appear most closely related to touch, while the roles of delta and gamma in tactile processing are less well-established. Lower frequency bands like theta are often linked to emotional and motivational states, while higher frequencies such as alpha and beta are associated with inhibitory processes (Klimesch, 2012; Klimesch et al., 2007; Knyazev, 2007). Increased theta activity has been linked to attentional engagement with salient sensory stimuli (Iannetti et al., 2008; Michail et al., 2016) and positive affect (Ackerley, Carlsson, et al., 2014; Aftanas et al., 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Krause et al., 2000; Maulsby, 1971). However, Von Mohr et al (2018) observed theta suppression during CT-optimal touch, although, their use of a still, eyes-closed condition might have induced a low-arousal state, which can also influence theta reduction (Klimesch, 1999; Knyazev et al., 2006; Mitchell et al., 2008).

Reductions in alpha and beta power are consistently observed during direct touch experiences (Diego et al., 2004; Michail et al., 2016; Singh et al., 2014; von Mohr et al., 2018b) and states of relaxation (Aftanas & Golocheikine, 2001; Diego et al., 2004; Field et al., 1996). Although it remains unclear if these reductions are driven by tactile sensations or anticipatory processes before touch occurs (Foxe et al., 1998; Michail et al., 2016; von Mohr et al., 2018a). Beta oscillations, in particular, have been linked to the perception of pleasant touch and positive affective states, with increased beta power correlating with enjoyable tactile experiences, especially in right hemispheric brain regions (Singh et al., 2014). This aligns with findings that slow, gentle touch can induce beta synchronisation, engaging socio-affective processes via CT-fibre activation (Ackerley et al., 2013). Reductions in alpha activity are observed not only during direct touch but also when observing touch, indicating sensorimotor engagement (Coll et al., 2015; Perry et al., 2010). Additionally, while alpha and beta power were reduced during explicit touch observation (participants indicated touch presence by pressing a button) compared to implicit observation (participants responded with sex identification prompts), touch images, in contrast to no-touch images, were associated with increased alpha and beta power (Schirmer & McGlone, 2019). These findings highlight the need for more research to disentangle the effects of real versus vicarious touch and to examine how factors like emotional closeness and touch type influence these neural patterns, especially in older adults.

In this study, we tracked touch behaviours and their frequency monthly over a four-month period using surveys. A subset of participants also participated in a lab session to assess the relationship between touch frequency and cognitive control and stress response during a psychological stress task. We recorded neural activity using electroencephalogram (EEG) and cardiovascular responses (HR and HRV using electrocardiogram [ECG]). Participants experienced different touch types (stroking, hugging, and handshakes) with close individuals, strangers, and through vicarious observation (vicarious touch) in an older adult sample. We focused on theta (4-8 Hz), beta (13-30 Hz), and alpha (8-13 Hz) oscillations across multiple scalp sites, to explore the neurophysiological effects of these touch interactions. Our hypotheses were as follows:

1. **Touch frequency and stress response:** Higher touch frequency would be associated with lower HR, increased HRV, and better cognitive control during the Stroop task compared to lower touch frequency. Experimental studies demonstrate that various types of partner touch, such as handholding, hugs, and stroking, reduce stress, lower blood pressure, and decrease HR. Increased touch frequency is linked to higher baseline oxytocin and lower cardiovascular responses, suggesting that frequent touch enhances emotional regulation and stress resilience (Coan et al., 2006; Jakubiak & Feeney, 2016, 2019; Light et al., 2005; Triscoli, Croy, Olausson, et al., 2017).
2. **Perceived pleasantness:** Stroking and hugging, especially when performed by close individuals, would be rated as more pleasant than handshakes, which would be perceived as neutral. Touch types differ significantly in body location, social context, and emotional response, with research indicating that while handshakes are experienced more frequently than desired, hugs and stroking are sought after more than received (Beßler et al., 2020; Schirmer et al., 2021). CT-fibres activated during gentle stroking are linked to comfort and positive affect, with CT-optimal touch rated as more pleasant than other touch types, while deep pressure from hugs and massages also elicits positive emotional responses (Case et al., 2021; Pawling et al., 2017).
3. **Cardiovascular effects of touch:** Direct touch, particularly with close individuals, would result in greater reductions in HR and increases in HRV than

vicarious touch, with more pronounced effects for stroking and hugging compared to handshakes. Experimental evidence indicates that various types of partner touch, such as handholding and hugging, mitigate stress and promote cardiovascular health (Coan et al., 2006; Jakubiak & Feeney, 2016; Light et al., 2005).

4. **Theta activity:** All touch conditions would increase theta activity compared to rest, indicating attention to sensory stimuli and positive affect, with the strongest theta responses expected for real touch from close individuals. This prediction aligns with findings that higher theta activity is associated with emotional and motivation states, as well as attentional engagement with salient stimuli (Iannetti et al., 2008; Michail et al., 2016).
5. **Beta and Alpha power:** Direct touch, particularly with close individuals, would result in greater beta activity increases and larger alpha activity reductions than vicarious touch, with more pronounced effects for stroking and hugging compared to handshakes. This is supported by evidence that beta oscillations correlate with pleasant tactile experiences and that reductions in alpha power occur during direct touch, indicating more robust neural responses to physical interaction than to vicarious touch (Coll et al., 2015; Schirmer & McGlone, 2019; Singh et al., 2014).

Methods

Participants

Sixty participants were recruited through opportunity sampling and advertisement. After exclusions due to withdrawals (one after the first and two after the third survey), 57 participants completed all four monthly surveys, with 24 pairs of close adults also participating in the EEG study. The remaining 9 did not participate in the EEG due to the unavailability of a close person to accompany them.

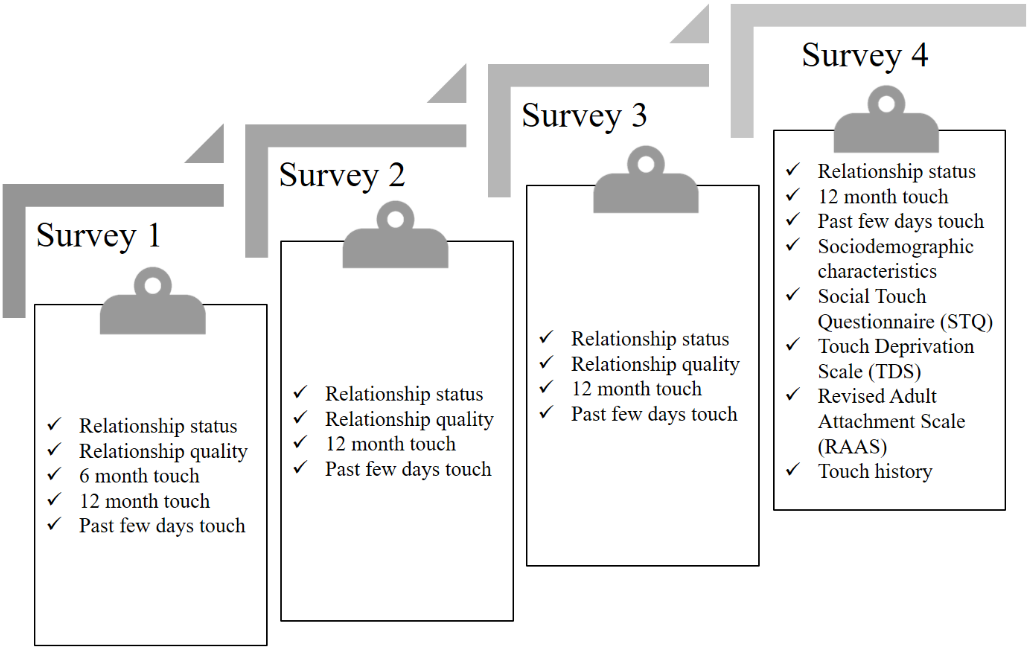
For the survey data analysis, the 57 participants included 39 women. Age ranged from 55 to 87 years (mean = 68.51, SD = 8.15). All participants identified as white, and 54 were right-handed or ambidextrous. 73.68% had a romantic partner and of those 85.71% lived with their romantic partner. The EEG analysis included 48 participants: 34 women, age ranged from 56 to 87 years (mean = 68.94, SD = 8.37). All identified as white, and 45 were right-handed or ambidextrous. 75% had a romantic partner and 91.67% lived with their romantic partner. 16 pairs were romantic partners, 7 were friends, and 1 pair were siblings.

All participants gave informed consent on Qualtrics (https://www.qualtrics.com) prior to testing. Participants were compensated with £5 vouchers per survey, with EEG participants receiving an additional £50 cash. This study adhered to the Declaration of Helsinki (1964) and was approved by the local ethics committee. A priori power analysis using G*Power version 3.1.9.2 (Faul et al., 2007) indicated that a sample size of 41 was needed to detect a medium effect of type of touch (hug, stroking, handshake) or experimental condition (close individual, stranger, vicarious) ($f = .25$, as outlined by Cohen (2013)) with 0.90 power. The power of paired t-tests to investigate significant effects arising from the ANOVA was also computed; for two-tailed tests, with power of 0.90, 36 participants are required to detect a medium effect (d=0.50, (Cohen, 2013)). Our sample of 48 participants is larger than other EEG studies of touch (N=36, Peled-Avron et al. (2018); N=28, von Mohr et al. (2018a)).

Materials

Surveys. Participants completed four surveys in Qualtrics (https://www.qualtrics.com), with variations in question content tailored to the study’s objectives and timing (see Figure 5.1). Relationship status, 12 months touch, and past few days touch were included in all surveys to consistently track touch behaviour. The first survey uniquely included 6 months touch to capture mid-term touch behaviour, while the Perceived Relationship Quality Components (PRQC) Inventory was included in the first three surveys to assess changes in relationship quality over time. Survey four introduced sociodemographic characteristics, the Social Touch Questionnaire (STQ), Touch Deprivation Scale (TDS), touch history related questions, and the Revised Adult Attachment Scale (RAAS) to provide a more comprehensive understanding of participants' touch experiences and attachment styles in broader psychosocial contexts. This ensured the collection of both consistent longitudinal data and new information without overburdening participants.

Figure 5.1. Overview of questions asked across four surveys



Relationship status and quality. Participants were asked about their romantic relationship status, including whether they have a romantic partner, if their relationship status had changed in the last six months, and if they live with their romantic partner, with "yes" or "no" response options. If participants indicated a change in relationship status, they were asked to specify the change with options: "Started a new relationship", "Ended a relationship", "Both ended a relationship and started a new relationship", "Became widowed", or "Other" (with space to specify). These questions were asked in all four monthly surveys. Relationship status did not change over the course of the four surveys for any of the participants.

For participants with a romantic partner, we measured global perceived relationship quality using the Perceived Relationship Quality Components (PRQC) Inventory (Fletcher et al., 2000). This was measures in the first three monthly surveys. The PRQC assesses six constructs: satisfaction, commitment, intimacy, trust, passion, and love. We used the shortened version of the PRQC, featuring one item from each construct: “How satisfied are you with your relationship?”, “How committed are you to your relationship?”, “How intimate is your relationship?”, “How much do you trust your partner?”, “How passionate is your relationship?”, and “How much do you love your partner?”. Responses were recorded on a 7-point Likert-type scale (1 = *not at all* to 7 = *extremely*). A total sum score was calculated where higher scores indicating higher relationship quality. When aggregated, these six items had good internal reliability (Cronbach’s alpha) across surveys; survey one = .78, survey two = .81, and survey three = .77. A repeated-measures ANOVA showed no significant difference in PRQC across three time points, $F(2,44) = 0.648$, $p = 0.528$, thus, an average PRQC score was calculated using PRQC scores from 3 months.

Past few days touch.

Touch partner, type and frequency. In all four surveys, participants reported the frequency of physical touch they experienced in the past few days (up to a week). Participants with a romantic partner were asked, “In the past few days (up to a week ago), how often have you engaged in hugging, kissing, caressing, or other close physical contact with a romantic partner?” All participants were asked, “In the past few days (up to a week ago), how often have you engaged in hugging, holding, or other close physical contact with another adult (other than a romantic partner)?” Response options included “Several times an hour”, “About once an hour”, “Many times a day”, “A few times a day”, “About once or twice a day”, “Less than once a day”, “Never”, “Don’t know”, and “Prefer not to say”. For comparative analyses with 6 and 12 months touch, these responses were recoded numerically, with “Never” assigned a value of 0 to “Several times an hour” assigned a value of 6. Participants reporting any touch over the past few days with a romantic partner were asked to specify the type of touch (“Hugging”, “Kissing”, “Caressing”, or “Other”) and its frequency (“A little”, “A moderate amount”, “A lot”, or “A great deal”). Note. “Handholding” was added as an option after the first month as a result of multiple participants specifying this as “Other” touch shared. Participants reporting any touch over the past few days with non-partners were asked to specify who touch was shared with (e.g., “Close friend”, “Family member”, “Colleague”, “Neighbour”, or “Acquaintance”), the type of touch (“Hugging”, “Holding”, or “Other”) with each specified individual, and its frequency (“A little”, “A moderate amount”, “A lot”, and “A great deal”).

To categorise participants based on their touch experiences, we created two cumulative variables: one for touch with a romantic partner and one for touch with other close adults over the four-month period. The scoring for touch frequency was as follows: “A little” = 1, “A moderate amount” = 2, “A lot” = 3, and “A great deal” = 4. Scores were summed across all four months to create a continuous variable for each context. To categorise participants based on the total frequency of touch interactions, tertiles were calculated using the distribution of touch frequencies across the entire sample. The “No partner touch” category was specific to participants who did not report any touch with a romantic partner across all four months. This categorisation was necessary because not all participants had a romantic partner. One participant had a romantic partner but reported no touch with their partner. For those who reported any partner touch, the remaining sample was divided into three groups representing “Low”, “Moderate”, and “High” touch, based on the 33rd and 66th percentiles of the distribution. The same tertile-based grouping was applied to non-partner touch frequencies, although there was no “No Touch” group for non-partners. We also calculated cumulative scores for each type of touch (hugging, kissing, caressing, and handholding) by summing responses for each type of touch across the four months. For handholding, data from three of the four monthly surveys were used. We chose not to retrospectively add handholding to the first survey based on “other” reports due to the small number of participants who mentioned it, which could introduce bias.

6 months touch. In the first survey, participants were asked about the frequency of touch shared over the past 6 months. Participants with a romantic partner were asked, “In the last 6 months, how often have you engaged in hugging, kissing, caressing, or other close physical contact with a romantic partner?” All participants were asked, “In the last 6 months, how often have you engaged in hugging, holding, or other close physical contact with another adult (other than a romantic partner)?” Response options were “Several times a week”, “About once a week”, “About once a month”, “Several times within the last 6 months, but less than once a month”, “About once or twice”, “Less than once”, “Never”, “Don’t know”, and “Prefer not to say”. For analyses, these responses were recoded numerically, with “Never” assigned a value of 0 to “Several times a week” assigned a value of 6.

12 months touch. In all four surveys, participants answered National Social Life, Health, and Aging Project (NSHAP) touch frequency questions regarding the past 12 months. These questions were included to assess the reliability of responses when asked monthly and to compare them with contemporaneous reports from the past few days. Participants with romantic partners were asked, “In the last 12 months, how often have you engaged in hugging, kissing, caressing, or other close physical contact with a romantic partner?” All participants were asked, “In the last 12 months, how often have you engaged in hugging, holding, or other close physical contact with another adult (other than a romantic partner)?” Response options included: “Several times a week”, “About once every week”, “About once a month", "Several times a year", "About once or twice a year", "Less than once a year", and "Never". For analyses, these responses were recoded numerically, with "Never" assigned a value of 0 to "Several times a week" assigned a value of 6. This was identical to the NSHAP questions, response options, and numerical coding.

Touch pleasantness. In all four surveys, participants were asked to rate the pleasantness of their indicated types of touch shared with the individuals they indicated sharing these touches with on a 9-point Likert-type scale (1 = *extremely unpleasant*, 5 = *neutral*, 9 = *extremely pleasant*). Specifically, they were asked:

1. "How pleasant do you find hugging your romantic partner to be?" (also applied to kissing, caressing, and other specified touches with romantic partners).
2. "How pleasant do you find hugging your close friend(s) to be?" (also applied to holding and other specified touches with close friends).
3. "How pleasant do you find hugging your family member(s) to be?" (also applied to holding and other specified touches with family members).

This same question format was used for touch interactions with colleagues, neighbours, acquaintances. An average pleasantness rating was calculated for each type of touch, with each individual, for every monthly survey across all participants.

Touch satisfaction. In all four surveys, participants with a romantic partner were asked, "Are you satisfied with the amount of touch that you share with your romantic partner?" Responses were recorded on a continuous scale from -1 (*unsatisfied – not enough*) to 1 (*unsatisfied – too much*), with 0 indicating *satisfaction*. Participants who responded "*unsatisfied – not enough*" were asked, "Which kind of touch do you want to share more of with your romantic partner?" with options for "Hugging", "Kissing", "Caressing", "Other" (with a box to specify), and "Prefer not to say." Participants who responded "*unsatisfied – too* *much*" were asked, "Which kind of touch do you wish to share less of with your romantic partner?" with the same response options.

All participants were then asked, "Are you satisfied with the amount of touch that you share with other adults (not a romantic partner)?" Responses were again recorded on a continuous scale from -1 (*unsatisfied – not enough*) to 1 (*unsatisfied – too much*), with 0 indicating *satisfaction*. Participants who responded, "*unsatisfied – not enough*" were asked, "Which kind of touch do you want to share more of with other adults (not a romantic partner)?" with options for "Hugging," "Holding," "Other" (with a box to specify), and "Prefer not to say". Participants who responded "*unsatisfied – too much*" were asked, "Which kind of touch do you wish to share less of with other adults (not a romantic partner)?" with the same response options.

Sociodemographic Characteristics. Sociodemographic data were collected in the final survey. Participants reported their age in years and their biological sex, with options including "Male," "Female," or "Prefer not to say." Ethnicity was categorised into several options: "White," "Mixed/multiple ethnic groups," "Asian/Asian British or American," "Black/African/Caribbean/Black British or American," "Arab," "Please specify if you identify with any other ethnic group," and "Prefer not to say."

Regarding educational attainment, participants were asked to select their highest qualification from a list that included "PhD or equivalent doctoral level qualification," "Masters or equivalent higher degree level qualification," "Postgraduate academic below-masters level qualification (e.g., certificate or diploma)," "Bachelors or equivalent first degree qualification," "A-levels," "As-levels," "Post-secondary vocational training," "GCSEs," "Completed primary school," and "None of the above." Handedness was also recorded, with options for "Right-handed," "Left-handed," or "Ambidextrous."

Participants were additionally asked whether they were currently living with family members other than a romantic partner, with “Yes” or “No” response options. Finally, they reported their household composition - the number of individuals living in their household.

Social Touch Questionnaire (STQ). Social Touch Questionnaire (STQ) data was collected in the final survey. The STQ, comprising of 20 questions, was developed by Wilhelm et al. (2001) and serves as a self-report instrument designed to assess an individual’s inclination and reaction towards situations involving interpersonal touch. By responding to statements like “I consider myself to be a ‘touchy-feely’ person” or “As a child, I was often cuddled by family members (e.g. parents, siblings),” participants provided insights into their sensitivity to social touch. Participants were asked to “indicate how characteristic or true each of the following statements is of you” on a 0-4 scale (0 = *not at all*, 1 = *slightly*, 2 = *moderately*, 3 = *very*, 4 = *extremely*). Some items are reversed scored. Scores on this scale are inversely related to the degree of preference for social touch; thus, lower scores indicate a stronger affinity for social touch, while higher scores signify a heightened aversion to engaging in, receiving, or observing social touch interactions. In this sample, internal consistency (Cronbach’s α) of the 20 questions was .82.

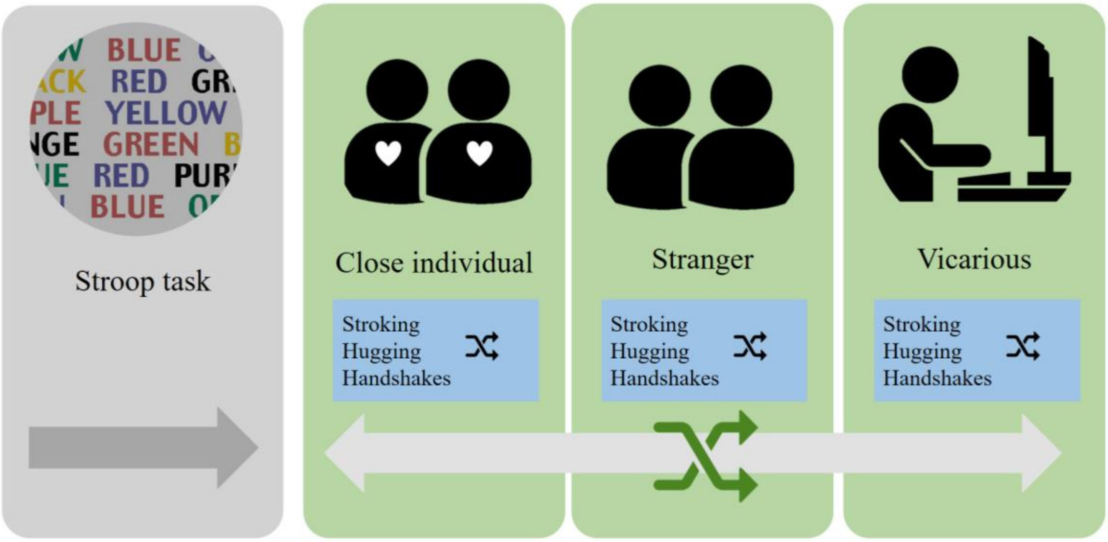
Touch Deprivation Scale (TDS). Data on the Touch Deprivation Scale (TDS) (Punyanunt-Carter et al., 2009) were collected during the final survey. This validated self-report questionnaire consists of 14 items assessing the frequency of touch in participants’ lives and their desire for touch. Participants rated each item on a 5-point Likert scale from “strongly disagree” to “strongly agree,” with higher scores indicating greater touch deprivation. The items are grouped into three categories: ‘Absence of touch,’ ‘Longing for touch,’ and ‘Use of sexual behaviour to be touched.’ Mean scores for each subcategory were calculated. Reliability analysis showed good internal consistency for the ‘Longing for touch’ (Cronbach’s α = .88) and acceptable consistency for the ‘Use of sexual behaviour to be touched' (Cronbach's α = .50) subcategory, while the 'Absence for touch' subscale exhibited poor reliability (Cronbach's α = .03) and was therefore excluded from analysis.

Revised Adult Attachment Scale (RAAS). The Revised Adult Attachment Scale (RAAS) data were collected in the final survey. The RAAS, developed by Collins (1996) based on the Adult Attachment Scale (Collins & Read, 1990), assesses individual differences in attachment style through 18 items divided into three subscales, each containing 6 items. The Close subscale measures comfort with closeness and intimacy (e.g., "*I find it relatively easy to get close to people*"). The Depend subscale evaluates comfort in relying on others and belief in their reliability (e.g., "*I find that people are never there when you need them*"). Finally, the Anxiety subscale assesses worries about rejection and abandonment (e.g., "*I am uncomfortable when anyone gets too emotionally close to me*"). Participants responded to each item based on their general orientation toward close relationships, using a 5-point Likert-type scale from 1 (*Not at all characteristic*) to 5 (*Very characteristic*). The Cronbach's alphas for the close, depend, and anxiety subscales were .61, .71, and .89, respectively.

Touch history. In the final survey, participants were asked additional questions related to touch. First, they were asked, "I recognise in my personal history the presence of negative/unpleasant experiences involving interpersonal touch," with response options of "Yes," "No," and "Prefer not to answer." Second, participants were asked, "Do you live with any condition (physical or mental) that may change the way you sense or perceive tactile (neutral, pleasant, or painful) stimulation?" with response options "Yes (please specify in the text box below" and "No." No participants reported adverse experiences with touch or conditions that alter their perception of tactile stimulation.

Experimental tasks.

Figure 5.2. *Experiment Task Sequence of Stroop Task Followed by Randomised Touch Interactions*



Note. Participants first completed the Stroop task, followed by three touch experimental conditions (close individual, stranger, vicarious) in randomised order. The order of touches (stroking, hugging, handshakes) in each touch experimental condition was also randomised.

Stroop task. A PsychoPy (Home — PsychoPy®) task was constructed to induce mental stress using the Stroop task paradigm (Stroop, 1992), adapted from the version developed by Yanagisawa et al. (2010). This interactive rendition of the classic Stroop task was designed to display two words, one in each of two rows on a computer screen. Participants were given the task of determining if the colour of the letters in the upper row matched the colour name printed in the lower row (see Figure 5.3). They indicated their response using the “yes” or “no” keys, designated as keys 1 and 2 on the top row on the keyboard, using their right hand (Yanagisawa et al., 2010). The “yes” key was positioned on the left and the “no” key on the right. Two-hundred trials were presented in random order, with each trial classified as either congruent, incongruent, or neutral (see Figure 3). The stimulus remained visible until a response was given or for a maximum of 2 seconds. In the congruent condition, the colour name was printed in a colour that corresponded to its semantic meaning, whereas in the incongruent condition, the colour name was printed in a colour that did not match its meaning. In the neutral trials, the upper row displayed sequences of Xs (XXXX) in colours red, green, blue, or yellow, while the lower row contained congruent colour words (‘RED’, ‘GREEN’, ‘BLUE’, and ‘YELLOW’).

To ensure sequential visual attention, the upper row appeared 100ms before the lower row (Schroeter et al., 2002). Equal probabilities of 50% were assigned to both “yes” and “no” responses. Immediate feedback was provided for correct or incorrect responses, displayed for one second. After practice, participants received information regarding the percentage of correct responses and the statement “84% of people were faster than you” in order to enhance the stressful nature of the task. The main Stroop task comprised 200 trials, each accompanied by feedback messages and a final feedback detailing the percentage of correct responses and the average reaction time. Correct answers triggered a screen displaying the message “Correct!” against a white background. Incorrect answers resulted in the message “Wrong!” accompanied by an angry face image from Tottenham et al. (2009) (refer to Chapter 4 Figure 4.3) beneath the text. Failure to respond within the 2-second window was met with the message “Too slow!” alongside the same angry face image. Messages and angry faces were chosen to enhance the stressful nature of the task. Prior to the main experiment, a practice session of seven trials was administered to ascertain correct response rates and reaction times for both the practice and experimental sessions. Following the Stroop task, participants watched 90 seconds of moving clouds.

Figure 5.3. *Instances of Single Stroop Task Trials are Shown for the Neutral, Congruent, and Incongruent Conditions*

Stroop test

Neutral **(60 trials)**	**Congruent** (70 trials)	**Incongruent** (70 trials)

XXXX	GREEN	GREEN
GREEN	RED	BLUE

Touch interactions. Each participant experienced three types of touch (stroking, hugging, and handshakes) across three experimental conditions: once with a close individual, once with a stranger, and once by watching vicarious videos. Both the order of the experimental conditions and the order of the touch types within each condition were randomised for each participant.

Close individual and stranger interactions. Each type of touch was performed three times. Participants completed three 10-second sessions of CT-optimal forearm stroking, three 10-second criss-cross style hugs (where arms crossed over the partner's shoulder and waist), and three 3-second handshakes (refer to Figure 5.4). During each interaction, participants were instructed to keep their eyes open and refrain from speaking. Before data collection, participants practiced each touch with their close individual, and with the stranger, until they felt comfortable with how to perform the interaction.

CT-optimal stroking was performed on the participant's forearm (palm faced down) with the index and middle fingers at a speed of 3 cm/s over a 10 cm range. This speed and region were selected based on previous research, which shows that slow touch on this area activates CT fibres (Kirsch et al., 2018; Pawling et al., 2017; von Mohr et al., 2018a). This was always on the participants right arm, which they positioned comfortably palm side down on a pillow (refer to Figure 5.4). The criss-cross hug was chosen for its egalitarian nature and common use, with a 10-second duration based on its reported pleasantness (Dueren et al., 2021). Handshakes were set at 3 seconds to maintain a natural feel, as informed by earlier studies (Feldhütter et al., 1990; Nagy et al., 2020).

For interactions with strangers, two female experimenters were typically present to ensure smooth execution of the touch protocols. Both experimenters were trained in the specific touches required for the study. One experimenter performed the interactions, while the second experimenter managed the technical aspects. This included pressing trigger buttons to synchronise the touch interaction with the EEG recording, keeping time for each interaction, and calling out the “start” and “stop” cues to signal the beginning and end of each touch. On occasions where only one experimenter was available, a mobile trigger button was used to send signals marking the start and finish of each interaction, while a timer placed behind the participants ensured accurate timing.

After each set of three repetitions of an interaction, participants were asked to rate its pleasantness on a 9-point Likert scale (1 = *extremely unpleasant*, 5 = *neutral*, 9 = *extremely pleasant*).

Figure 5.4. *CT-Optimal Stroking, Hugging, and Handshakes With a Stranger*

Stroking	**Hugging**	**Handshake**
		

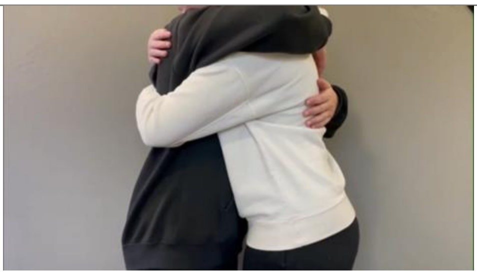
Vicarious videos. Three vicarious touch videos were created for the purpose of this experiment and were presented to participants in Psychopy (version 2021.2.2). Each video portrayed a different form of touch: CT-optimal stroking, hugging, and a handshake, with each video lasting 10 seconds (see Figure 5.5). To minimise bias related to physical attributes, the actors' heads were kept out of frame, and they wore loose-fitting clothing to minimise sex differences, aiming to present the actors as gender-neutral as possible. All videos were filmed against a plain grey background, and no audio was included.

In the stroking video, one actor's right forearm rested on a table while another actor stroked the forearm using their index and middle fingers at a speed of 3 cm/s over a 10 cm range. The hugging video showed two actors approaching each other from opposite sides and embracing in a criss-cross arm pattern hug for 10 seconds. In the handshake video, two actors approached from opposite sides and performed a handshake with their right hands for 3 seconds, followed by conversational hand movements for the last 5 seconds.

Similar to touch interactions, each video was presented three times to participants, with 3-second intervals between repetitions. During these intervals, a black fixation cross was displayed on a white background. Before the onset of the first of three videos, participants were shown a brief instruction on a white screen stating: "You will now watch a video of people hugging/shaking hands/stroking another person's forearm". After viewing each set of three repetitions, participants were asked to rate the pleasantness of the video on a 9-point Likert scale (1 = *extremely unpleasant*, 5 = *neutral*, 9 = *extremely pleasant*).

Figure 5.5. *Vicarious Hug Video Stimuli at 3 Seconds (Left) and 6 Seconds (Right)*

Stroking

Hugging		
Handshake		

Apparatus

Electroencephalogram (EEG) was recorded during each experimental condition (with a close individual, a stranger, and during vicarious video viewing) using 64 scalp electrodes mounted on an EasyCap (Easycap, Herrsching, Germany). The electrodes were referenced online to the left earlobe, and offline re-referenced to the average of all scalp electrodes. An additional electrode was placed on the right earlobe. EEG signals were amplified using a NeuroScan SynAmps2 amplifier, with a band-pass filter set between 0.05 and 100 Hz and digitised at a sampling rate of 1000 Hz. Electrode impedance was maintained below 30 kΩ throughout the recordings.

To monitor heart rate (HR) and heart rate variability (HRV), two additional bipolar electrodes were placed on the right clavicle and left hip to record the electrocardiogram (ECG) from participants, with the same filter settings as the EEG.

Procedure

Survey data collection occurred over four months, with participants completing monthly Qualtrics surveys. For the 48 participants involved in the laboratory experiment, the fourth survey was conducted in the laboratory, alongside physiological measurements during touch interactions. Participants not involved in the laboratory study completed the fourth survey remotely.

In the laboratory, participants arrived in pairs but completed the experiment sequentially. After providing informed consent and completing the final survey, EEG and ECG electrodes were attached to the first participant, who then completed the Stroop task. Meanwhile, electrodes were prepared for the second participant. Once the Stroop task was completed, the first participant moved on to the recording of 2.5 minutes of sitting rest and then 2.5 minutes of standing rest with eyes open to serve as within-participant baselines for comparisons against EEG obtained from touch conditions. After this the participants completed the touch interaction tasks.

The touch interactions involved three types of touch (stroking, hugging, and handshakes) across three experimental conditions (close individual, stranger, and vicarious video touch). The order of experimental conditions and touch types was randomised for each participant, with each type of touch repeated three times. Participants practiced each touch interaction with their close individual and the stranger before the actual trials. After each set of touches, participants rated the pleasantness of the experience.

Once the first participant had completed all tasks, the second participant began the sequence of tasks with the Stroop, followed by a randomised order of experimental conditions and touch type order within each condition.

Data analyses

Survey data. Survey data were cleaned and analysed in R (V4.1.1; R Core Team, 2021). Descriptive statistics summarised participant demographics and the frequency of physical touch interactions with romantic partners and non-partners across the four-month survey period (see Table 5.1). Continuous variables were reported as means and standard deviations, while categorical variables were presented as percentages.

To explore relationships between psychological and sociodemographic variables and touch frequency, Pearson correlation coefficients were calculated for both partner touch and non-partner touch, after testing for normality. The Benjamini-Hochberg correction was applied to adjust for multiple comparisons, with significance set at $p < .05$. This analysis aimed to understand how factors such as attachment styles (RAAS subscales) and touch deprivation (Touch Deprivation Scale subscales) relate to touch frequency.

Descriptive statistics (means and standard deviations) also provided an overview of the frequency and pleasantness of various types of reported touch, at each of four time points (see Table 5.2) and participants' satisfaction with touch quantity (see Table 5.3). To assess the reliability of self-reported touch frequency, means and standard deviations were computed for touch interactions over three retrospective periods: the past 12 months, the past 6 months, and the past few days (see Table 5.4). Pearson correlation coefficients, corrected using the Benjamini-Hochberg method, were used to evaluate the consistency of touch reports across these periods, with separate analyses for touch with romantic partners and non-partners.

Behavioural data.

Stroop task. The analysis of Stroop task performance focused on two key metrics: accuracy (percentage of correct responses) and reaction time (RT). These metrics were analysed in relation to participants' reported frequency of touch with romantic partners and other individuals over the past four months. Group comparisons were conducted for each touch frequency category using mean and standard deviations for Stroop accuracy and reaction time (see Table 5.5). To assess the relationship between touch frequency and Stroop task performance, Benjamini-Hochberg adjusted correlation analyses were conducted between touch frequency and both Stroop task accuracy and mean RT.

A one-way ANOVA was used to check for baseline differences in sitting resting heart rate (HR) and heart rate variability (HRV) between groups of touch frequency of touch between romantic partners and non-partners over the four-month period. After this, paired t-tests were used to compare HR and HRV during rest (sitting) and the Stroop task across different touch frequency groups for both romantic partners and non-partners to assess whether there were any significant differences in HR and HRV during a stressful task based on the amount of touch reported over the last four months. This analysis was completely separately for each group.

Experimental touch pleasantness. Descriptive statistics (means and standard deviations) were presented for pleasantness ratings across the touch type conditions (stroking, hugging, handshakes) in each experimental condition (close individual, stranger, vicarious) (see Table 5.6). A 3 (touch type) x 3 (experimental condition) repeated measures ANOVA was then conducted to assess significant differences in touch pleasantness ratings, followed by Bonferroni-corrected post hoc comparisons to explore specific differences between touch types and experimental conditions (see Appendix Table C.2).

EEG and ECG data.

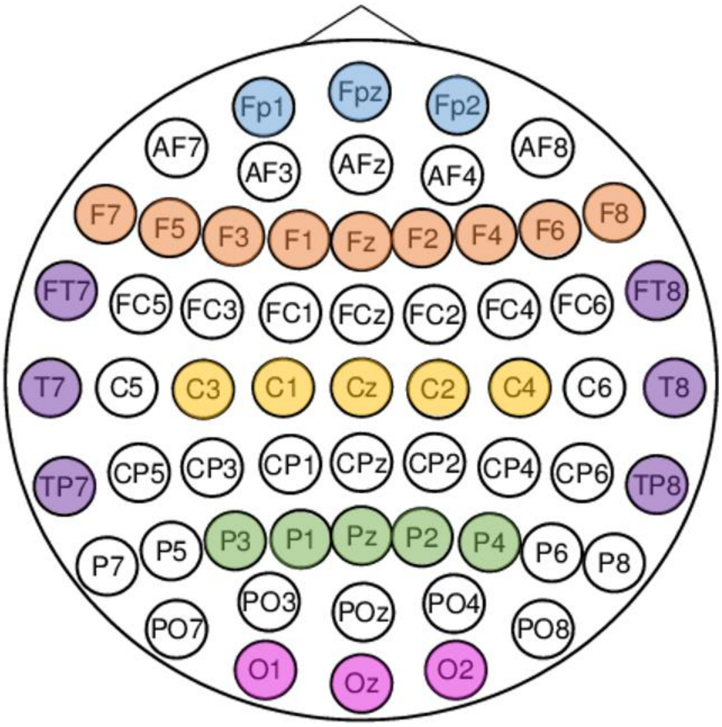
Pre-processing. EEG and ECG data were pre-processed using BrainVision Analyzer 2.0. A band-pass filter between 0.05 and 40 Hz was applied to reduce noise, with channels with artefacts corrected via spline interpolation and ocular artefacts removed using the Gratton and Coles method (1983). The data were then re-referenced to the average of all scalp electrodes. For each of the three 10-second iterations of each touch type (stroking, hugging, handshakes), in each experimental condition (close individual, stranger, vicarious), 8-second segments were created for stroking and hugging, starting 1 second after the onset of each touch iteration and ending 9 seconds after onset (removing EEG activity from the first and last second of the touch event). For handshakes, in which physical contact lasted three seconds only, 2-second segments were created, starting 0.5 seconds after touch event onset and ending 2.5 seconds after touch event onset. Finally, each of the 8-second segments was further divided into 2-second segments, as were sitting and standing resting EEG data, and ECG data.

A Fast Fourier Transform (FFT) analysis was applied on the EEG data using BranVision Analyzer 2.0 to extract spectral power across three frequency bands of interest: theta (4-8 Hz), alpha (8-13 Hz), and beta (13-30 Hz). The spectral power was averaged across all available 2-second segments for each touch type within each experimental condition. The averaged data were then exported to SPSS version 28 for statistical analysis. Average spectral power for each frequency band was calculated for electrode clusters across six scalp regions: prefrontal (Fpz, Fp1, Fp2), frontal (Fz, F1, F2, F3, F4, F5, F6, F7, F8), central (Cz, C1, C2, C3, C4), parietal (Pz, P1, P2, P3, P4), temporal (FT7, T7, Tp7, FT8, T8, Tp8), and occipital (Oz, O1, O2) (see Figure 5.6), for a similar approach to von Mohr et al. (2018a). To normalise the data, log transformation was applied.

Significant differences were observed between sitting and standing postures during the resting EEG (see Appendix Table C.1), and therefore, spectral power was not averaged across these conditions. Instead, the resting condition was matched to the majority of conditions in which participants were sitting or standing whilst recordings were made for each comparison. All comparisons for stroking between different experimental conditions (close individuals, strangers, vicarious) used the sitting rest as a baseline because participants were sitting for stroking in all experimental conditions. In contrast, all comparisons for hugging and handshakes between different experimental conditions used the standing rest as a baseline because participants were standing for hugging and handshakes with close individuals and strangers (but not for watching vicarious videos). For touch type analyses, all comparisons within the close individual experimental condition and the stranger experimental condition, between different touch types, used the standing rest as the baseline because participants were standing for hugging and handshakes with close individuals and strangers (but not for stroking). However, all comparisons within the vicarious experimental condition between different touch types used the sitting rest as the baseline because participants were sitting for all vicarious videos.

For ECG data, R peaks were detected using the pulse artefact correction tool of BrainVision Analyzer 2.0, and time information was extracted. R-peak data for each touch type in each experimental condition, the Stroop task, and the resting conditions were exported to Excel for preparation and then analysed in SPSS version 28.0. In Excel, heart rate (HR, in beats per minute) for each touch type and experimental condition, was calculated from the interval between R peaks in milliseconds, and heart rate variability (HRV) was calculated as the standard deviation of the normal to normal sinus mode initiated R-R intervals (SDNN) in milliseconds. To normalise the data, log transformation was applied to HRV.

Figure 5.6. *Electrode Layout Highlighting Clusters for Six Scalp Regions*



Note. The electrode layout corresponds to the 64-channel EasyCap configuration used in the study. Highlighted clusters indicate the six scalp regions from which average spectral power was calculated: prefrontal (blue), frontal (orange), central (yellow), parietal (green), temporal (purple), and occipital (pink). These clusters were used for analysis of theta (4-8 Hz), alpha (8-13 Hz), and beta (13-30 Hz) frequency bands.

Analyses. For ECG statistical analyses, descriptive statistics for HR and HRV were calculated for each touch type within each experimental condition. Descriptive statistics (means and standard deviations) of HR and HRV were presented for each touch type with each experimental condition, during the Stroop task and during sitting and standing resting conditions (see Table 5.9). Repeated measures ANOVAs were used to assess the main effects of experimental condition (close individual, stranger, vicarious) on HR and HRV for each touch type (stroking, hugging, handshakes), with comparisons made to baseline (rest conditions) measurements as well. Greenhouse-Geisser corrections were applied where violations of sphericity were detected. Where significant main effects were found, we conducted post hoc pairwise comparisons using Bonferroni correction to control for Type 1 error. These comparisons were used to further explore differences between specific conditions (e.g., comparing HR and HRV during stroking by a close individual vs. a stranger) (see Tables 5.10, 5.11, 5.12, and 5.13). Partial eta squared (ηp^2) was used to estimate the effect size of significant main effects, with values based on conventional standards (small = .01, medium = .06, large = .14).

For EEG statistical analyses, descriptive statistics (see Table 5.14) were followed by repeated-measures ANOVAs, which were conducted separately for experimental condition and touch type. For the experimental condition analysis, each touch type (stroking, hugging, handshakes) was analysed for each experimental condition (close individual, stranger, vicarious) and scalp region (pre-frontal, frontal, central, parietal, temporal, and occipital), with comparisons made to baseline (rest) measurements as well. This analysis was performed on log-transformed values for theta, alpha, and beta frequencies. For the touch type analysis, each experimental condition was analysed separately, comparing stroking, hugging, handshakes across scalp regions. Where significant main effects were found, Bonferroni-corrected post hoc pairwise comparisons were used to further explore differences between specific (see Tables 5.15, 5.16, 5.17, 5.18, 5.19, and 5.20). Effect sizes are reported as partial eta-squared (ηp^2), with thresholds for small (.01), medium (.06), and large (.14) effects (Cohen, 2013). Greenhouse-Geisser corrections were applied where assumptions of sphericity were violated.

The functional role of different EEG frequency bands is still debated, partly due to the variety of contexts in which EEG is recorded (Knyazev et al., 2006). However, there is growing consensus that each frequency band reflects distinct brain functions. Therefore, our EEG results are presented by frequency band. For instance, low-frequency bands like theta may relate to motivational and emotional activity, while higher frequency bands, such as alpha and beta, are more associated with inhibitory processes (Klimesch, 2012; Klimesch et al., 2007; Knyazev, 2007).

Results

Survey results

Participant characteristics. Table 5.1 provides a summary of participant characteristics and their reported touch frequency with both romantic partners and non-partners over four months. Several trends were observed. A negative correlation was found between increasing age and both romantic partner and non-partner touch frequency over four months. Participants with romantic partners report more touch with non-partners than participants without romantic partners. Participants with higher relationship quality (PRQC) report more touch with both romantic partners and non-partners. Participants who report a stronger affinity for social touch (STQ) and participants who feel more comfortable with closeness and relying on others (RAAS close and depend subscales) also report more touch with non-partners than participants with less affinity and comfort with closeness and relying on others. Lastly, those who report less touch with romantic partners also report more longing for touch (TDS subscale) and greater anxiety about rejection (RAAS anxiety subscale).

Benjamini-Hochberg corrected Correlation analyses examined the relationship between touch frequency and the sociodemographic and psychological variables reported in Table 5.1. Partner touch frequency was positively correlated with household composition (r = .54, p < .001), indicating that compared to those living alone, those living with other people naturally share more touch with romantic partners. A strong positive correlation was also found with relationship quality (r = .80, p < .001), suggesting higher relationship quality with more partner touch. Regarding touch frequency with non-partners, there was a negative correlation with total Social Touch Questionnaire (STQ) score, indicating that individuals who have a greater affinity for social touch share more touch with non-partners (lower scores indicate a greater affinity with social touch) (*r* = -.49, *p* = .001). Also, we found a positive correlation with the adult attachment closeness subscale of the RAAS (*r* = .38, *p* = .022), suggesting that individuals who have a stronger comfort with closeness and intimacy touch non-partners more. Other sociodemographic and psychological variables did not show significant correlations with frequency of touch with non-partners.

Table 5.1. *Demographic Characteristics of the Sample by Reported Touch Frequency with Romantic Partners and Other Non-Partners*

	Romantic Partners				**Non-Partners**		
	No Touch (N=16)	Low Touch (N=14)	Moderate Touch (N=13)	High Touch (N=14)	Low Touch (N=24)	Moderate Touch (N=15)	High Touch (N=18)
Age (mean(SD))	69.40 (5.11)	69.10 (9.40)	69.20 (8.34)	66.30 (9.83)	69.40 (8.30)	68.30 (6.27)	67.60 (9.56)
Women (%)[a]	75	71.40	76.90	50	62.50	73.30	72.20
Highest Qualification (%)							
GCSEs or below	31.20	25	12.50	31.20	43.80	18.80	37.50
AS/A level or vocational training	23.50	17.60	35.30	23.50	41.20	29.40	29.40
Bachelor's degree or higher	26.10	30.40	21.70	21.70	43.50	26.10	30.40
Romantic Partner (%)[b]	6.25	100	100	100	62.50	73.30	88.90
Living with Partner (%)[c]	6.25	78.60	92.30	85.70	62.50	66.70	61.10

Household Composition (%)							
Lives alone	72.20	16.70	5.56	5.56	44.40	27.80	27.80
Lives with one other person	7.14	32.10	25	35.70	46.40	21.40	32.10
Lives with two or more persons	11.10	11.10	44.40	33.30	22.20	44.40	33.30
Total Social Touch Questionnaire (mean (SD))[d]	29.80 (10.50)	27.90 (11.10)	29.30 (11.50)	29.00 (11.90)	32.20 (9.49)	29.90 (10.60)	24.10 (11.90)
Longing for Touch (mean (SD))[e]	2.69 (1.12)	2.04 (1.05)	1.63 (.71)	1.99 (1.17)	2.16 (1.08)	1.97 (.83)	2.18 (1.29)
Sex for Touch (mean (SD))[f]	2.56 (1.14)	2.68 (.75)	2.92 (.61)	2.86 (1.22)	2.75 (1.06)	2.73 (.94)	2.75 (.88)
RAAS Close Subscale (mean (SD))[g]	3.49 (.70)	3.77 (.68)	4.06 (.67)	3.74 (.55)	3.51 (.62)	3.91 (.62)	3.94 (.70)
RAAS Depend Subscale (mean (SD))[h]	2.96 (.82)	3.26 (.84)	3.76 (.67)	3.36 (.66)	3.09 (.84)	3.40 (.76)	3.54 (.70)
RAAS Anxious Subscale (mean (SD))[i]	2.59 (1.20)	2.27 (.93)	1.65 (.97)	1.94 (.74)	2.16 (.99)	2.18 (.93)	2.08 (1.19)
Average PRQC (mean (SD))[j]	1.21 (4.83)	31.50 (6.89)	36 (3.43)	38.60 (4.15)	22.20 (18.10)	24.70 (17.0)	31.50 (12.30)

Note. Participants who reported no touch with a romantic partner over the four months were categorised as 'no partner touch,' the majority of whom were single. Those with any partner or non-partner touch were divided into tertiles: 'low,' representing the lowest 33.3% of the data; ‘moderate,’ comprising the middle 33.3%; and ‘high,’ encompassing the highest 33.3%. However, the distributions for partner and non-partner touch differ, so these categories cannot be directly compared.

[a] Percentage of women relative to men.

[b] Percentage of participants with a romantic partner versus those without.

[c] Percentage of participants living with their romantic partner versus those who are not.

[d] Mean (SD) of the total Social Touch Questionnaire, where lower scores indicate a stronger affinity for social touch.

[e, f] Mean (SD) scores for absence of touch, longing for touch, and sex for touch. Higher scores reflect greater feelings of touch absence, longing, and sex for touch, respectively. Items are rated on a 5-point Likert scale.

[g, h, i] Participants rated their general orientation toward close relationships on a 5-point Likert scale (1 = *Not at all characteristic* to 5 = *Very characteristic*). Higher scores in the Close subscale (h) reflect greater comfort with closeness and intimacy; the Depend subscale (i) reflects greater comfort in relying on others; and the Anxious subscale (j) reflects greater worry about rejection.

[j] Average score of three months of PQRC, recorded on a 7-point Likert scale (1 = *Not at all* to 7 = *Extremely*), with higher scores indicating better relationship quality.

Monthly touch frequency and pleasantness reports. Each month, participants reported the types of touch they shared over the past few days (up to a week), with whom they shared them, and the frequency of each touch. Partner hugging was reported the most frequently, while partner kissing and handholding were less common (refer to Table 5.2). Partner caressing was the least frequent touch with partners, but all types of partner touches were rated similarly pleasant. Among non-romantic relationships, family hugging was the most frequent, followed by friend hugging. Family touches were rated as more pleasant than friend touches, although both were reported less frequently than partner touches. Colleague, neighbour, and acquaintance touches were the least common and least pleasant compared to touches with partners, family, and friends. Both the frequency and pleasantness of partner touches remained more stable over time than those with others.

Table 5.2. *Means and Standard Deviations (SD) of Frequency and Pleasantness of Touches Shared with Different Individuals*

Type of Touch and Relationship	Frequency Mean (SD)				Pleasantness Mean (SD)			
	Time 1	Time 2	Time 3	Time 4	Time 1	Time 2	Time 3	Time 4
Partner hugging	1.64 (.98)	1.55 (1.04)	1.60 (.94)	1.74 (.96)	8.62 (.64)	8.61 (.68)	8.43 (.76)	8.58 (.65)
Partner kissing	1.50 (.92)	1.36 (.98)	1.45 (1.04)	1.31 (1.12)	8.19 (1.14)	8.38 (.87)	8.08 (1.23)	8.25 (1.09)
Partner caressing	.91 (1.14)	.81 (.99)	.86 (1.16)	.83 (1.12)	8.11 (1.36)	8.74 (.65)	8.41 (.93)	8.52 (.70)
Partner handholding		1.10 (1.03)	1.26 (1.23)	1.43 (1.17)		8.72 (.61)	8.40 (.86)	8.35 (.88)
Friend hugging	.63 (.82)	.63 (.84)	.68 (.78)	.91 (.87)	7.13 (1.06)	7.40 (.94)	6.99 (1.44)	7.61 (1.05)
Friend holding	.14 (.52)	.14 (.64)	.05 (.29)	.05 (.40)	7.28 (1.22)	7.43 (1.50)	9.00 (.00)	9.00 (.00)
Family hugging	.88 (.97)	.88 (.97)	.72 (.84)	.84 (1.08)	8.07 (1.09)	8.34 (.78)	7.93 (1.23)	8.38 (1.00)
Family holding	.32 (.78)	.25 (.69)	.14 (.55)	.30 (.84)	8.22 (.96)	8.21 (1.27)	8.98 (.05)	8.75 (.70)
Colleague hugging	.05 (.29)	.07 (.32)	.05 (.29)	.07 (.32)	6.30 (1.18)	7.67 (1.23)	6.95 (1.20)	7.57 (1.45)

Colleague holding	-	.02 (.13)	-	-	-	8.8	-	-
Neighbour hugging	.07 (.26)	.07 (.26)	.11 (.31)	.11 (.36)	6.42 (1.00)	5.62 (.74)	6.70 (1.82)	7.64 (1.14)
Neighbour holding	-	-	-	.02 (.13)	-	-	-	2.9
Acquaintance hugging	.23 (.63)	.16 (.46)	.07 (.26)	.14 (.52)	6.39 (1.72)	5.63 (1.73)	6.92 (1.65)	7.06 (1.58)
Acquaintance holding	.07 (.37)	.02 (.13)	.04 (.27)	.04 (.27)	6.55 (1.24)	7.00	7.9	9.00

Note. In monthly surveys, participants reported types of touch shared over the past few day (up to a week) and with whom. For each reported touch, they rated its frequency on a 5-point scale (0 = *None* to 4 = *A great deal*), answering questions such as, “In the past few days (up to a week ago), how much hugging have you shared with your romantic partner?” Average frequencies and pleasantness ratings (on a 9-point scale: 1 = *Extremely unpleasant* to 9 = *Extremely pleasant*, where 5 = *Neutral*) are presented for each touch type. All participants were included in the calculations of averages, even if they reported no touch. Handholding with a partner was added starting from Time 2. The number of responses per cell varies, with a range of 1 to 37 responses (mean = 13.8, median = 7) for cells where there were more than zero responses.

Satisfaction with touch quantity. On average, participants felt unsatisfied with the quantity of touch they shared with both romantic partners and other close adults and this remained consistent over time (refer to Table 5.3). Specifically, they felt that they did not share enough touch with these individuals. These feelings of non-satisfaction were much stronger for touch with romantic partners compared to non-partners. Participants reported wanting more of all types of touch with romantic partners (hugging, kissing, caressing, and handholding) and other adults (hugging and holding).

Table 5.3. *Means and Standard Deviations of Partner and Non-Partner Quantity Satisfaction Across Four Time Points*

Time Point	Partner Touch Quantity Satisfaction	Other Individual Touch Quantity Satisfaction
Time 1	-.29 (.46)	-.09 (.30)
Time 2	-.30 (.47)	0.00 (.26)
Time 3	-.29 (.46)	-.15 (.36)
Time 4	-.21 (.49)	-.03 (.31)

Note. Means (standard deviation) are reported. Responses were recorded on a continuous scale from -1 (*unsatisfied – not enough*) to 1 (*unsatisfied – too much*), with 0 indicating *satisfaction*.

Reliability of retrospective self-report touch frequency. Table 5.4 presents the frequency of touch with romantic partners and non-partners across different timeframes: the past 12 months, 6 months, and the past few days. For romantic partners, touch frequency remains stable when participants report retrospectively over 6 or 12 months, ranging between once and several times per week. However, when asked about the past few days, touch frequency increases to once or twice a day, or even a few times daily. For non-partners, touch was consistently reported at lower frequencies, typically between once a week and once a month over the 6 and 12-month periods. However, when asked about the past few days, participants reported more frequent touch, between less than once a day and once or twice daily. This pattern indicates that while touch reports remain stable over longer periods, shorter timeframes and finer response options reveal more frequent touch interactions with both romantic partners and non-partners.

Table 5.4. *Descriptive Statistics of Partner and Non-Partner Touch Frequency Over the Last 12 Months, 6 Months, and Few Days, Across Surveys*

Time Point	**Romantic Partner (Mean (SD))**	**Non-partner (Mean (SD))**
Last 12 months [a]		
Time 1	5.34 (1.46)	4.56 (1.36)
Time 2	5.52 (1.06)	4.58 (1.18)
Time 3	5.68 (.93)	4.67 (1.34)
Time 4	5.73 (.87)	4.60 (1.43)
Last 6 months [b]	5.62 (1.03)	4.25 (1.58)
Last few days [c]		
Time 1	2.57 (1.13)	1.33 (1.06)
Time 2	2.41 (1.09)	1.15 (.95)
Time 3	2.49 (1.14)	1.28 (.96)
Time 4	2.54 (1.05)	1.24 (1.07)

Note.

[a] Response options for the past 12 months were from 0 = *Never, 1 = Less than once a year,* 2 = *About once or twice a year*, 3 = *Several times a year*, 4 = *About once a month*, 5 = *About once every week* and 6 = *Several times a week.*

[b] Response options for the last 6 months, response options were and 0 = *Never,* 1 = *Less than once,* 2 = *About once or twice,* 3 = *Several times within the last 6 months, but less than once a month,* 4 = *About once a month,* 5 = *About once a week* and 6 = *Several times a week.*

[c] Response options for the past few days, response options were 0 = *Never,* 1 = *Less than once a day*, 2 = *About once or twice a day,* 3 = *A few times a day* , 4 = *Many times a day*, 5 = *About once an hour*, and 6 = *Several times an hour*.

Correlations and stability of touch reports over time. Benjamini-Hochberg corrected Pearson correlation analyses assessed the stability of participants' touch frequency reports over time. For romantic partners, strong and significant positive correlations were found between Time 1 and subsequent time points (*r* = .86 to .92, *p* < .001); Time 2 and subsequent time points (*r* = .82 to .92, *p* < .001); and Time 3 and 4 (*r* = .88, *p* < .001), indicating high consistency in reports of partner touch frequency over the last 12 months. Short-term reports (over the past few days) also showed significant correlations, though lower correlations were found between Time 1 and subsequent time points (*r* = .53 to .74, *p* < .001); Time 2 and subsequent time points (*r* = .60 to .79, *p* < .001); and Time 3 and 4 (*r* = .69, *p* < .001), reflecting less stability compared to longer-term reports.

For non-partners, correlations of the touch frequency over the last 12 months were significant but lower than those for romantic partner touch between Time 1 and subsequent time points (*r* = .69 to .83, *p* <.001); Time 2 and subsequent time points (*r* = .74 to .83, *p* < .001); and Time 3 and 4 (*r* = .72, *p* < .001), suggesting more variability in non-partner touch reports. Short-term correlations for non-partner touch between Time 1 and subsequent time points (r = .60 to .63, p < .001); Time 2 and subsequent time points (*r* = .55 to .63, *p* < .001); and Time 3 and 4 (*r* = .53, *p* < .001), showed greater variability compared to long-term reports. Overall, long-term reports were more stable than short-term ones, and romantic partner touch reports were more stable over the long term compared to non-partners, while both types of reports were relatively variable in the short term.

Behavioural Data

Stroop Task Performance.

Accuracy and Reaction Time Based on Four Month Touch Frequency. Table 5.5 presents the results of the Stroop task, comparing participants' accuracy and reaction times (RT) based on their reported frequency of touch with romantic partners and non-partners. Benjamini-Hochberg adjusted correlation analysis revealed no correlation between romantic partner touch frequency over the last 4 months and Stroop correct answers (*r* = .04, *p* = .769) or mean Stroop RT (*r* = -.08, *p* = .769). The correlations between other individual touch frequency over the last 4 months were also non-significant with Stroop correct answers (r = -.23, p = .217) and mean Stroop RT (r = .18, p = .234). This suggests that touch frequency with romantic partners and other individuals did not affect Stroop task performance.

Table 5.5. *Stroop Task Accuracy and Reaction Time by Frequency of Touch with Romantic Partners and Non-Partners*

	Romantic Partner				**Non-partners**		
	No Touch (N=16)	Low Touch (N=14)	Moderate Touch (N=13)	High Touch (N=14)	Low Touch (N=24)	Moderate Touch (N=15)	High Touch (N=18)
Stroop Correct Answers (%)[l]	84.30 (10.40)	86.10 (17.40)	85.90 (14.30)	85.20 (8.53)	86.80 (12.00)	91.50 (7.10)	79.10 (14.60)
Mean Stroop RT (mean (SD))[m]	1.13 (.21)	1.05 (.25)	1.13 (.20)	1.10 (.20)	1.08 (.24)	1.08 (.23)	1.15 (.16)

Note. Participants reporting no partner touch over four months were categorised as ‘No Touch’ (mostly without a romantic partner). Those with non-zero scores were divided into tertiles, creating ‘Low’, ‘Moderate’, and ‘High’ touch groups for both partner and other adult touch. We also examined whether the number of correctly answered congruent and incongruent trials and mean RTs for congruent and incongruent trials, were correlated with the frequency of touch with romantic partners and non-partners. We found no statistically significant correlations.

[l] Percentage of correct Stroop answers out of 198 trials.

[m] Mean and standard deviations of reaction time of Stroop trial response measures in seconds out of a possible 2 seconds.

HR and HRV during the Stroop task. A one-way ANOVA was performed to check for differences in sitting resting heart rate (HR) and heart rate variability (HRV) between romantic partner and non-partner touch frequency over four months groups. There were no statistically significant differences between partner touch groups for resting HR, *F*(3, 43) = 1.52, *p* = .223, or HRV *F*(3, 43) = 1.10, *p* = .358. Similarly, no significant differences were found between non-partner touch groups for HR, *F*(2, 44) = .41, *p* = .666, and HRV *F*(2, 44) = .65, *p* = .528. Paired t-tests were then used to compare HR and HRV during rest (sitting) and the Stroop task across different touch frequency groups for both with romantic partners and non-partners. The analyses were completely separately for each group.

For romantic partners, there were significant differences in HR between rest and Stroop task performance across all touch groups. Specifically, participants who reported no partner touch in the last four months showed a significant increase in HR during the Stroop task compared to rest, *t*(11) = 3.71, *p* = .003, with a mean difference of 4.96 beats per minute (bpm) (95% CI: 2.01 to 7.90). Similarly, significant HR differences were found in the Low Touch group, *t*(10) = 4.95, *p* < .001, mean difference = 10.36 bmp (95% CI: 5.70 to 15.02), the Moderate Touch group, *t*(9) = 5.13, *p* < .001, mean difference = 5.03 bpm (95% CI: 2.81 to 7.24), and the High Touch group, *t*(10) = 3.04, *p* = .012, mean difference = 8.78 bpm (95% CI: 2.35 to 15.21). HRV did not significantly differ between rest and Stroop task performance across No Touch (*t*(11) = -0.54, *p* = .603), Low Touch (*t*(10) = 0.08, *p* = .936), Moderate Touch (*t*(9) = -0.43, *p* = .675), and High Touch (*t*(10) = 0.04, *p* = .971) groups with romantic partners.

For non-partners, similar significant increases in HR during the Stroop task were observed across the different touch groups. Participants in the Low Touch group showed a significant increase in HR, *t*(17) = 4.87, *p* < .001, with a mean difference of 6.49 bpm (95% CI: 3.68 to 9.31). The Moderate Touch group also showed significant HR increases, *t*(10) = 2.99, *p* = .014, with a mean difference of 6.68 bpm (95% CI: 1.70 to 11.67), as did the High Touch group, *t*(14) = 4.36, *p* < .001, with a mean difference of 8.66 bpm (95% CI: 4.40 to 12.92). HRV did not significantly differ between rest and Stroop task performance across

Low Touch (*t*(17) = -0.46, *p* = .654), Moderate Touch (*t*(10) = -0.56, *p* = .588), and High Touch (*t*(14) = 1.02, *p* = .325) groups with non-partners.

These results show a consistent increase in HR from rest to the Stroop task across all touch groups, without evidence that higher touch frequency moderates the HR response during a stressful task. This suggests that the influence of touch on stress may be state-dependent, as increased touch over the past four months does not appear to improve resilience during a stressful task. In contrast, no significant differences were found for HRV, likely because HRV reflects longer-term autonomic regulation and is less responsive to short-term stress tasks compared to HR, which reacts more immediately to acute stress.

Experimental Touch Pleasantness. Table 5.6 presents pleasantness ratings for stroking, hugging, and handshakes across experimental conditions. Hugging was rated as the most pleasant touch across all experimental conditions, with close individual hugs rated the highest overall, while handshakes were rated the least pleasant, especially vicarious handshakes. A 3 (touch type) x 3 (experimental condition) ANOVA revealed significant effects for both touch type, *F*(2, 92) = 26.59, *p* < .001, and experimental condition, *F*(2, 92) = 13.89, *p* < .001, as well as a significant interaction between them, *F*(4, 184) = 8.37, *p* < .001. Post hoc comparisons (Appendix Table C.2) showed that close individual hugging was the most pleasant, followed by close individual stroking and stranger hugging, while vicarious touches were generally rated lower, with vicarious hugging rated highest among them.

Table 5.6. *Pleasantness Ratings of CT-Optimal Stroking, Hugging, and Handshakes Vicariously Watched, with Close Individuals, and with Strangers*

Touch Type	**Close individual Pleasantness (Mean (SD))**	**Stranger Pleasantness (Mean (SD))**	**Vicarious Pleasantness (Mean (SD))**
Stroking	7.02 (1.52)	6.54 (1.47)	5.74 (1.73)

Hugging	8.17 (1.08)	6.96 (1.54)	7.26 (1.39)
Handshake	6.27 (1.78)	6.48 (1.65)	5.51 (1.04)

Note. Participants rated pleasantness on a 9 point scale from 1 = not at all pleasant to 9 = extremely pleasant, where 5 = neutral.

Heart Rate (HR) and Heart Rate Variability (HRV)

Descriptive Statistics. In Table 5.7 we present the heart rate (HR) and heart rate variability (HRV) recorded from the experimental conditions (close individual, stranger, vicarious) and touch type conditions (stroke, hugging, handshakes). We performed a paired t-test to check if there is a significant difference in sitting and standing HR, and found that they are significantly different, $t(46) = -7.58$, $p < .001$. The mean difference between the two conditions was -6.41 (95% CI: -8.11, -4.71), indicating that standing HR was significantly higher than sitting HR. However, HRV was not significant different between the two postures ,$t(46) = 1.25$, $p = .219$, with a mean difference of 0.11 (95% CI: -0.06, 0.28). Thus, significant HR differences should be interpreted with caution when comparing conditions with different postures, such as vicarious hugs and real hugs.

Table 5.7. *HR and HRV Means (Standard Deviation) for Each Touch Type in Each Experimental Condition, the Stroop Task, and Rest Conditions*

Experiment condition		HR (bpm)	HRV
Close Individual	**Stroke**	61.86 (8.70)	3.33 (0.86)
	Hugging	68.90 (10.12)	3.82 (0.97)
	Handshake	72 .71 (13.58)	3.46 (1.46)
Stranger	**Stroke**	62.13 (9.02)	3.37 (0.83)
	Hugging	69.54 (9.59)	3.58 (0.71)
	Handshake	73.34 (11.74)	3.05 (1.30)
Vicarious	**Stroke**	61.76 (8.71)	3.06 (1.14)
	Hugging	62.63 (8.60)	3.09 (0.91)
	Handshake	63.48 (8.20)	3.17 (1.30)

Stroop		72.64 (8.77)	3.60 (0.80)
Rest	**Sitting**	64.12 (8.92)	3.53 (0.64)
	Standing	70.29 (10.96)	3.41 (0.77)

Note. Mean (standard deviation) HR (bpm) and log-transformed HRV (SDNN) are reported. More positive log-transformed HRV indicate higher HRV.

Experimental Condition HR and HRV Effects.

Stroking. Significant main effects on HR and HRV were found for stroking across experimental conditions (close, stranger, vicarious, sitting rest): HR: $F(3, 135) = 7.56$, $p < .001$, $\eta_p^2 = .14$, and HRV: $F(2.39, 107.58) = 7.38$, $p < .001$, $\eta_p^2 = .14$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.8) showed significantly lower HR during stroking across all experimental conditions compared to rest. There were no significant HR differences between experimental conditions for stroking. In contrast, HRV was significantly lower during vicarious stroking than rest (see Table 5.9). There were no other significant HRV differences between stroking and rest, or between experimental conditions.

Hugging. Significant main effects for hugging in different experimental conditions (close, stranger, vicarious, standing rest) were found in HR: $F(3, 132) = 31.65$, $p < .001$, $\eta_p^2 = .42$, and HRV: $F(3, 132) = 12.54$, $p < .001$, $\eta_p^2 = .22$. Post hoc pairwise comparisons with Bonferroni correction indicated lower HR during vicarious hugging compared to rest and compared to real hugs (see Table 5.8). No significant HR differences were found between real hugs and rest or between close individual and stranger hugs. However, HRV was significantly higher during close individual hugs compared to rest, whereas HRV was significantly lower during vicarious hugs compared to rest and real hugs (see Table 5.9). Posture-related HR differences may have contributed to the significantly lower HR during vicarious hugs, where participants were seated.

Handshakes. Significant main effects for handshakes in different experimental conditions (close, stranger, vicarious, standing rest) were observed in HR: $F(2.12, 93.37) = 18.33$, $p < .001$, $\eta_p^2 = .29$, but not HRV: $F(2.48, 106.68) = 2.49$, $p = .076$, $\eta_p^2 = .06$. Post hoc pairwise comparisons of HR with Bonferroni correction revealed that HR was lower during vicarious handshakes compared to both rest and real handshakes (see Table 5.8). Additionally, HR was significantly higher during handshakes with strangers compared to rest. No significant differences in HRV were observed (see Table 5.9). The lower HR during vicarious handshakes compared to real ones may have been due to posture differences rather than an effect on affect or arousal.

Table 5.8. *Post Hoc Pairwise Comparisons with Bonferroni Correction on HR Between Conditions (Close, Stranger, Vicarious, and Rest) for Stroking, Hugging, and Handshakes*

	Stroking	**Hugging**	**Handshakes**
Close vs. stranger	-.24 (.47)	-.20 (.74)	-.42 (1.70)
Close vs. vicarious	.14 (.49)	6.35 (.97)**	9.27 (1.97)**
Stranger vs. vicarious	.38 (.53)	6.55 (.83)**	9.69 (1.37)**
Close vs. rest	-2.21 (.56)**	-.67 (.79)	2.54 (1.46)
Stranger vs. rest	-1.97 (.65)*	-.47 (.82)	2.96 (.90)*
Vicarious vs. rest	-2.35 (.66)**	-7.01 (.85)**	-6.73 (1.23)**

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., close – stranger). **p* < .05, ***p* < .01 corrected values.

Table 5.9. *Post Hoc Pairwise Comparisons with Bonferroni Correction on Log-Transformed HRV Between Conditions (Close, Stranger, Vicarious, and Rest) for Stroking, Hugging, and Handshakes*

	Stroking	**Hugging**	**Handshakes**
Close vs. stranger	-.05 (.07)	.17 (.14)	.58 (.27)

Close vs. vicarious	.25 (.10)	.72 (.13)**	.23 (.25)
Stranger vs. vicarious	.30 (.11)	.55 (.12)**	-.35 (.26)
Close vs. rest	-.19 (.09)	.40 (.14)*	.10 (.20)
Stranger vs. rest	-.15 (.09)	.23 (.10)	-.48 (.18)
Vicarious vs. rest	-.45 (.12)**	-.33 (.11)*	-.13 (.19)

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., close – stranger). *$p < .05$, **$p < .01$ corrected values.

Touch Type HR and HRV Effects.

Close. HR and HRV analyses revealed significant main effects for different touch types (stroking, hugging, handshakes) with a close individual: HR: $F(1.82, 80.05) = 24.19$, $p < .001$, $\eta_p^2 = .36$ and HRV: $F(1.97, 86.78) = 3.15$, $p = .049$, $\eta_p^2 = .07$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.10) revealed significantly lower HR during stroking with a close individual compared to standing rest, and both hugging and handshakes. Though this could have been influenced by posture differences, as sitting resting HR was significantly lower than standing resting HR (see Table 5.7), and the resting condition in these comparisons was standing HR, while participants were sitting during the delivery of stroking. HRV was significantly higher during hugging a close individual than during standing rest or stroking (see Table 5.11). No other significant differences in HR or HRV were observed between touch types with close individuals or when compared to standing rest.

Stranger. HR and HRV analyses revealed significant main effects for touch types (stroking, hugging, handshakes) with a stranger: HR: $F(2.39, 105.18) = 42.75$, $p < .001$, $\eta_p^2 = .49$, and HRV: $F(1.60, 70.38) = 4.75$, $p = .017$, $\eta_p^2 = .10$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.10) revealed significantly lower HR during stroking with a stranger compared to standing rest, hugging, and handshakes. Although this also could have been influenced by posture differences, as sitting resting HR was significantly lower than standing resting HR, and the resting condition in these comparisons was standing HR, while participants were sitting during the delivery of stroking. In contrast, HR was significantly higher during stranger handshakes compared to standing rest, as well as stroking and hugging. No significant differences in HR were found between hugging and standing rest. There were also no significant HRV differences between any touches with a stranger and standing rest, although HRV was significantly higher during hugging compared to both stroking and handshakes (see Table 5.11).

Vicarious. HR and HRV analyses revealed significant main effects for touch types (stroking, hugging, handshakes): HR: $F(2.08, 95.53) = 4.12$, $p = .018$, $\eta_p^2 = .08$ and HRV: $F(1.81, 83.24) = 4.36$, $p = .019$, $\eta_p^2 = .09$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.10) revealed that HR was lower during vicarious stroking compared to sitting rest, but there were no significant differences between vicarious touches, or between hugging and handshakes and sitting rest. While HRV was significantly lower during both vicarious stroking and hugging compared to sitting rest (see Table 5.11).

Table 5.10. *Post Hoc Pairwise Comparisons with Bonferroni Correction on HR Between Touch-Type Conditions (Stroking, Hugging, Handshakes, and Rest) for Touch Shared with Close Individuals, Strangers, and Vicarious*

	Close individuals	**Strangers**	**Vicarious**
Stroke vs. hug	-7.30 (.96)**	-6.91 (.82)**	-.85 (.32)
Stroke vs. handshake	-10.79 (1.75)**	-10.46 (1.24)**	-1.71 (.77)
Hug vs. handshake	-3.50 (1.74)	-3.55 (.93)*	-.86 (.80)
Stroke vs. rest	-8.41 (.92)**	-7.40 (.96)**	-2.25 (.65)**
Hug vs. rest	-1.11 (.87)	-.49 (.82)	-1.40 (.57)
Handshake vs. rest	2.38 (1.45)	3.06 (.91)*	-.54 (.87)

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., stroking - hugging). **p* < .05, ***p* < .01 corrected values.

Table 5.11. *Post Hoc Pairwise Comparisons with Bonferroni Correction on HRV Between Touch-Type Conditions (Stroking, Hugging, Handshakes, and Rest) for Touch Shared with Close Individuals, Strangers, and Vicarious*

	Close individuals	**Strangers**	**Vicarious**
Stroke vs. hug	-.46 (.14)**	-.28 (.07)**	-.03 (.10)
Stroke vs. handshake	-.09 (.22)	.29 (.20)	-.11 (.20)
Hug vs. handshake	.38 (.22)	.57 (.20)*	-.08 (.18)
Stroke vs. rest	-.01 (.09)	-.05 (.10)	-.47 (.12)**
Hug vs. rest	.45 (.14)*	.23 (.10)	-.44 (.08)**
Handshake vs. rest	.08 (.19)	-.34 (.18)	-.36 (.16)

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., stroking - hugging). **p* < .05, ***p* < .01 corrected values.

HR and HRV Key Findings Summary. Stroking and hugging showed calming effects that were absent during handshakes. Lower HR was observed during stroking across all experimental conditions, while higher HR was observed during stranger handshakes than other stranger touches. However, HRV was more responsive to hugging, with higher HRV observed during real hugs, especially those with close individuals.

EEG Results

Spectral Power Descriptive Statistics. In Table 5.12 we present the log-transformed spectral power for theta, beta, and alpha recorded in experimental conditions (close individual, stranger, vicarious) and touch type conditions (stroke, hugging, handshakes) across all scalp sites.

Table 5.12. *Log-Transformed Spectral Power for Theta, Beta, and Alpha in Close Individual, Stranger, and Vicarious, and Rest (Sitting and Standing) Experimental Conditions Across Stroking, Hugging, and Handshake Touch-Types, in Prefrontal, Frontal, Central, Parietal, Temporal, and Occipital Scalp Sites*

	Prefrontal	Frontal	Central	Parietal	Temporal	Occipital
Theta						
Close Individual						
Stroke	.02 (.96)	-1.07 (.68)	-2.03 (.49)	-1.85 (.55)	-1.23 (.60)	-.94 (.63)
Hugging	.63 (1.20)	-.62 (.87)	-1.55 (1.11)	-1.39 (1.08)	-.64 (1.10)	-.68 (.92)
Handshake	.80 (1.20)	-.46 (1.01)	-1.48 (1.31)	-1.16 (1.39)	-.57 (1.07)	-.36 (.78)
Stranger						
Stroke	.03 (1.05)	-.98 (.78)	-1.88 (.89)	-1.70 (.86)	-1.08 (.88)	-.93 (.60)
Hugging	.88 (1.34)	-.61 (.81)	-1.60 (.88)	-1.40 (.88)	-.62 (.89)	-.77 (.71)
Handshake	.96 (1.17)	-.43 (.86)	-1.41 (1.05)	-1.17 (1.01)	-.43 (1.05)	-.26 (.58)
Vicarious						
Stroke	-.29 (.79)	-.83 (.61)	-1.92 (.81)	-1.75 (.76)	-.98 (.67)	-1.01 (.57)
Hugging	.13 (.98)	-.83 (.72)	-1.88 (.79)	-1.62 (.78)	-1.01 (.92)	-.79 (.76)
Handshake	.13 (.75)	-.28 (.71)	-1.81 (.67)	-1.46 (.74)	-.57 (.69)	-.69 (.59)
Rest						
Sitting	-.85 (.86)	-1.37 (.57)	-1.95 (.58)	-1.89 (.68)	-1.40 (.58)	-1.45 (.68)
Standing	-.73 (.96)	-1.21 (.65)	-1.91 (.53)	-1.84 (.63)	-1.28 (.55)	-1.38 (.67)
Beta						
Close Individual						
Stroke	-1.58 (.71)	-2.02 (.74)	-2.75 (.77)	-2.90 (.60)	-1.27 (.65)	-2.05 (.64)
Hugging	-1.35 (.79)	-2.09 (.68)	-2.66 (.95)	-2.62 (.85)	-.80 (.83)	-1.63 (.76)
Handshake	-1.31 (1.01)	-1.86 (.93)	-2.66 (1.20)	-2.70 (1.04)	-.74 (.90)	-1.63 (.83)
Stranger						
Stroke	-1.58 (.73)	-2.09 (.62)	-2.71 (.69)	-2.81 (.65)	-1.30 (.62)	-2.08 (.64)
Hugging	-1.17 (.79)	-2.01 (.67)	-2.57 (.80)	-2.59 (.60)	-.61 (.85)	-1.52 (.67)

Handshake	-1.07 (.93)	-1.85 (.87)	-2.59 (.90)	-2.59 (.74)	-.45 (.99)	-1.34 (.99)
Vicarious						
Stroke	-1.66 (.76)	-2.22 (.72)	-2.86 (.76)	-2.98 (.59)	-2.09 (.73)	-2.29 (.60)
Hugging	-1.55 (.82)	-2.17 (.80)	-2.80 (.77)	-2.93 (.67)	-1.94 (.86)	-2.29 (.65)
Handshake	-1.68 (.75)	-2.22 (.81)	-3.00 (.85)	-3.16 (.56)	-2.06 (.80)	-2.40 (.62)
Rest						
Sitting	-1.83 (.77)	-2.19 (.66)	-2.68 (.68)	-2.77 (.62)	-1.86 (.54)	-2.39 (.64)
Standing	-1.75 (.86)	-2.01 (.77)	-2.71 (.69)	-2.78 (.58)	-1.81 (.57)	-2.31 (.65)
Alpha						
Close Individual						
Stroke	-.89 (.76)	-1.67 (.70)	-2.35 (.76)	-2.01 (.84)	-1.19 (.68)	-1.22 (.88)
Hugging	-.36 (.96)	-1.35 (.71)	-1.92 (1.05)	-1.60 (1.05)	-.77 (.89)	-.56 (.90)
Handshake	-.44 (1.01)	-1.41 (.85)	-2.19 (1.19)	-1.81 (1.20)	-.91 (.93)	-.85 (.81)
Stranger						
Stroke	-.89 (.80)	-1.64 (.68)	-2.21 (.90)	-1.89 (.87)	-1.08 (.76)	-1.17 (.75)
Hugging	-.16 (.88)	-1.36 (.59)	-1.96 (.82)	-1.57 (.82)	-.72 (.72)	-.64 (.80)
Handshake	-.18 (1.00)	-1.31 (.63)	-2.10 (.89)	-1.75 (.81)	-.70 (.83)	-.64 (.70)
Vicarious						
Stroke	-1.18 (.61)	-1.70 (.52)	-2.34 (.76)	-2.07 (.72)	-1.36 (.73)	-1.49 (.55)
Hugging	-.92 (.74)	-1.65 (.63)	-2.30 (.77)	-2.01 (.75)	-1.29 (.85)	-1.39 (.66)
Handshake	-1.03 (.63)	-1.54 (.56)	-2.45 (.67)	-2.17 (.61)	-1.32 (.68)	-1.44 (.55)
Rest						
Sitting	-1.13 (.87)	-1.56 (.82)	-1.85 (.92)	-1.45 (1.07)	-1.14 (.79)	-1.03 (1.08)
Standing	-.99 (.83)	-1.38 (.77)	-1.82 (.86)	-1.36 (1.05)	-1.05 (.77)	-.86 (1.07)

Note. Data is presented as mean (standard deviation). Greater negative values in log-transformed data reflect lower activity.

Theta.

Experimental Condition.

Stroking. Analyses on theta activity revealed significant main effects, for stroking across experimental conditions (close, stranger, vicarious, sitting rest), *F*(2.19, 103.11) = 6.82, $p = .001$, $\eta_p^2 = .13$, scalp site, $F(2.61, 122.60) = 210.52$, $p < .001$, $\eta_p^2 = .82$, and their interaction, $F(5.63, 264.62) = 11.04$, $p < .001$, $\eta_p^2 = .19$. To further investigate, we conducted repeated measures ANOVAs including only the within-subjects factor of experimental condition (close, stranger, vicarious, rest) at each scalp site for stroking. The main effect of experimental condition was statistically significant at the prefrontal, $F(3, 141) = 13.54$, $p < .001$, $\eta_p^2 = .22$, frontal, $F(3, 141) = 10.54$, $p < .001$, $\eta_p^2 = .18$, temporal, $F(2.01, 94.29) = 5.55$, $p = .005$, $\eta_p^2 = .11$, and occipital scalp sites, $F(3, 141) = 16.06$, $p < .001$, $\eta_p^2 = .26$. However, the main effect of experimental condition was not statistically significant at the central scalp site, $F(1.46, 68.38) = .57$, $p = .514$, $\eta_p^2 = .01$, nor at the parietal scalp site, $F(1.65, 77.45) = 1.11$, $p = .325$, $\eta_p^2 = .02$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.13) showed significantly higher theta activity during stroking in all experimental conditions compared to rest at prefrontal, frontal, and occipital scalp sites, with additional differences at the temporal scalp site for vicarious stroking. There were no significant differences in theta activity between the experimental conditions.

Hugging. Analyses on theta activity revealed significant main effects for hugging across experimental conditions (close, stranger, vicarious, standing rest), $F(2.15, 101.22) = 12.45$, $p < .001$, $\eta_p^2 = .21$, scalp site, $F(2.57, 120.70) = 190.56$, $p < .001$, $\eta_p^2 = .80$, and their interaction, $F(6.36, 298.80) = 10.01$, $p < .001$, $\eta_p^2 = .18$. To further investigate, we conducted repeated measures ANOVAs including only the within-subjects factor of experimental condition at each scalp site for hugging. The main effect of experimental condition was statistically significant at prefrontal, $F(3, 141) = 25.52$, $p < .001$, $\eta_p^2 = .35$, frontal, $F(2.27, 106.64) = 9.45$, $p < .001$, $\eta_p^2 = .17$, parietal, $F(1.99, 93.38) = 3.85$, $p = .025$, $\eta_p^2 = .08$, temporal, $F(2.13, 99.97) = 7.70$, $p < .001$, $\eta_p^2 = .14$, and occipital scalp sites, $F(2.37, 111.15) = 11.44$, $p < .001$, $\eta_p^2 = .20$. However, the main effect of experimental condition was not statistically significant at the central scalp site, $F(1.72, 80.88) = 3.04$, $p =$

.061, $\eta_p^2 = .06$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.13) showed significantly higher theta activity during hugging, across all experimental conditions compared to rest at prefrontal, frontal, and occipital scalp sites. This was more widespread for real hugs, especially with strangers (parietal and temporal scalp sites). Additionally, theta activity was significantly higher during stranger hugs compared to vicarious hugs at the prefrontal scalp site. The differences between rest and vicarious hugging were larger and more widespread than those between sitting and standing rest (refer to Appendix Table C.1.), suggesting that these differences were unlikely due to posture. We did not find any other differences between hugging experimental conditions.

Handshakes. Analyses on theta activity revealed significant main effects for handshakes in different experimental conditions (close, stranger, vicarious, standing rest), $F(2.48, 116.32) = 20.96$, $p < .001$, $\eta_p^2 = .31$, scalp site, $F(2.81, 132.26) = 187.14$, $p < .001$, $\eta_p^2 = .80$, and their interaction, $F(7.31, 349.26) = 12.83$, $p < .001$, $\eta_p^2 = .21$. To further investigate, we conducted repeated measures ANOVAs including only the within-subjects factor of experimental condition at each scalp site for handshakes. The main effect of experimental condition was statistically significant at all scalp sites. Including the prefrontal, $F(3, 141) = 33.40$, $p < .001$, $\eta_p^2 = .42$, frontal, $F(3, 141) = 17.21$, $p < .001$, $\eta_p^2 = .27$, central, $F(2.00, 93.79) = 5.13$, $p = .008$, $\eta_p^2 = .10$, parietal, $F(2.37, 111.21) = 7.07$, $p < .001$, $\eta_p^2 = .13$, temporal, $F(2.41, 113.20) = 14.08$, $p < .001$, $\eta_p^2 = .23$and occipital scalp sites, $F(2.40, 112.57) = 38.70$, $p < .001$, $\eta_p^2 = .45$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.13) showed significantly higher theta activity during handshakes, across all experimental conditions, compared to rest at the prefrontal, frontal, parietal, temporal, and occipital scalp sites, including the central site for stranger handshakes. Theta activity was higher during real handshakes compared to vicarious handshakes at the prefrontal scalp site, and this was more widespread for strangers, including central and occipital sites. As these differences did not occur at scalp sites showing significantly different resting theta activity between sitting and standing (see Appendix Table C.1), posture cannot explain the observed differences.

Table 5.13. *Post Hoc Pairwise Comparisons with Bonferroni Correction on Log-Transformed Theta Activity Between Conditions (Close Individual, Stranger, Vicarious, and Rest) Across Scalp Sites (Prefrontal, Frontal, Central, Parietal, Temporal, and Occipital) for Stroking, Hugging, and Handshakes*

	Prefrontal Theta	**Frontal Theta**	**Central Theta**	**Parietal Theta**	**Temporal Theta**	**Occipital Theta**
Stroking						
Close vs. stranger	-.01 (.14)	-.10 (.10)	-.15 (.13)	-.15 (.12)	-.15 (.12)	-.02 (.07)
Close vs. vicarious	.32 (.16)	-.25 (.11)	-.11 (.12)	-.10 (.17)	-.25 (.11)	.07 (.09)
Stranger vs. vicarious	.32 (.15)	-.15 (.09)	.04 (.07)	.05 (.08)	-.10 (.08)	.08 (.08)
Close vs. rest	.88 (.16)**	.30 (.09)**	-.08 (.05)	.04 (.07)	.16 (.08)	.50 (.08)**
Stranger vs. rest	.88 (.18)**	.40 (.11)**	.06 (.15)	.19 (.15)	.32 (.13)	.52 (.09)**
Vicarious vs. rest	.56 (.16)**	.55 (.10)**	.02 (.14)	.14 (.14)	.41 (.12)**	.44 (.10)**
Hugging						
Close vs. stranger	-.25 (.20)	-.01 (.09)	.05 (.08)	.02 (.10)	-.01 (.12)	.09 (.10)
Close vs. vicarious	.50 (.20)	.21 (.16)	.34 (.20)	.23 (.20)	.38 (.21)	.10 (.17)
Stranger vs. vicarious	.75 (.21)**	.22 (.15)	.29 (.17)	.22 (.17)	.39 (.19)	.01 (.14)
Close vs. rest	1.36 (.20)**	.58 (.13)**	.36 (.17)	.46 (.17)	.65 (.16)**	.69 (.15)**
Stranger vs. rest	1.61 (.20)**	.59 (.15)**	.31 (.14)	.44 (.15)*	.66 (.14)**	.61 (.11)**
Vicarious vs. rest	.86 (.18)**	.37 (.12)*	.03 (.12)	.23 (.13)	.27 (.15)	.59 (.13)**
Handshakes						
Close vs. stranger	-.16 (.21)	-.03 (.14)	-.07 (.12)	.01 (.16)	-.14 (.13)	-.10 (.10)
Close vs. vicarious	.67 (.19)**	-.18 (.14)	.33 (.14)	.30 (.17)	.004 (.14)	.34 (.13)
Stranger vs. vicarious	.83 (.19)**	-.15 (.15)	.40 (.14)*	.29 (.16)	.14 (.16)	.43 (.11)**
Close vs. rest	1.53 (.20)**	.75 (.16)**	.43 (.20)	.69 (.22)*	.72 (.16)**	1.02 (.14)**
Stranger vs. rest	1.69 (.20)**	.78 (.14)**	.50 (.18)*	.68 (.17)**	.85 (.17)**	1.12 (.12)**

Vicarious vs. rest	.86 (.15)**	.93 (.12)**	.10 (.12)	.38 (.13)*	.71 (.11)**	.69 (.09)**

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., close – stranger). *$p < .05$, **$p < .01$ corrected values.

Touch Type.

Close Individual. Analyses on theta activity showed significant main effects for different touch types (stroking, hugging, handshakes) with a close individual, $F(1.78, 83.52) = 20.95$, $p < .001$, $\eta_p^2 = .31$; scalp site, $F(2.87, 134.92) = 179.53$, $p < .001$, $\eta_p^2 = .79$, and their interaction, $F(6.35, 298.51) = 7.78$, $p < .001$, $\eta_p^2 = .14$. To further investigate, we repeated the ANOVA including only the within-subjects factor of touch type (stroke, hug, handshake, standing rest) at each scalp site for touch shared with close individuals. The main effect of touch type was statistically significant across all scalp sites, including the prefrontal, $F(3, 141) = 28.89$, $p < .001$, $\eta_p^2 = .38$, frontal, $F(2.21, 103.66) = 15.86$, $p < .001$, $\eta_p^2 = .25$, central, $F(1.20, 56.44) = 6.09$, $p = .012$, $\eta_p^2 = .12$, parietal, $F(1.49, 70.03) = 8.98$, $p = .001$, $\eta_p^2 = .16$, temporal, $F(1.93, 90.54) = 15.17$, $p < .001$, $\eta_p^2 = .24$, and the occipital scalp sites, $F(2.33, 109.71) = 22.48$, $p < .001$, $\eta_p^2 = .32$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.14) revealed greater theta activity during all touches with close individuals compared to rest at prefrontal and occipital sites, with more widespread effects for hugs and handshakes at frontal and temporal sites. However, during stroking, theta activity was significantly lower than rest at the central site. Comparing touch types with close individuals, hugging and handshakes showed higher theta activity than stroking at prefrontal, frontal, central, parietal, and temporal scalp sites, and the occipital site for handshakes. No significant differences in theta were found between hugging and handshakes. Since posture-related differences (sitting vs. standing rest) were only significant at frontal and temporal sites (see Appendix Table C.1), and theta was consistently higher during hugging and handshakes than stroking at nearly all sites, it suggested that posture did not account for the observed theta differences.

Stranger. Analyses on theta activity showed significant main effects for different touch types (stroking, hugging, handshakes) with a stranger, $F(2.37, 111.17) = 30.08$, $p < .001$, $\eta_p^2 = .39$; scalp site, $F(2.46, 115.42) = 168.64$, $p < .001$, $\eta_p^2 = .78$, and their interaction, $F(6.92, 325.16) = 12.04$, $p < .001$, $\eta_p^2 = .20$. To further investigate, we repeated the ANOVA including only the within-subjects factor of touch type (stroke, hug, handshake, standing rest) at each scalp site for touch shared with strangers. The main effect of touch type was statistically significant across all scalp sites, including the prefrontal, $F(3, 141) = 35.97$, $p < .001$, $\eta_p^2 = .43$, frontal, $F(3, 141) = 17.80$, $p < .001$, $\eta_p^2 = .28$, central, $F(1.72, 81.04) = 7.54$, $p = .002$, $\eta_p^2 = .14$, parietal, $F(1.89, 89.03) = 11.62$, $p < .001$, $\eta_p^2 = .20$, temporal, $F(2.41, 113.22) = 18.30$, $p < .001$, $\eta_p^2 = .28$, and occipital sites, $F(3, 141) = 38.84$, $p < .001$, $\eta_p^2 = .45$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.14) showed greater theta activity during all strangers touches compared to rest at the prefrontal and occipital sites. Hugging and handshakes produced more widespread effects, with increased theta activity at frontal, parietal, and temporal sites, while hugging also showed increases at the central site. Additionally significantly higher theta activity was observed during hugging and handshakes than stroking at multiple scalp sites. Theta activity was also higher during handshakes than hugs at the occipital site. Posture-related differences were only significant at the frontal and temporal sites (see Appendix Table C.1). Given that theta activity was consistently higher during hugging and handshakes than stroking at almost all sites, it suggested that posture alone did not account for the observed differences in theta.

Vicarious. Analyses on theta activity showed that the main effect was statistically significant for vicarious touch types (stroking, hugging, handshakes), $F(2.40, 112.76) = 13.67$, $p < .001$, $\eta_p^2 = .23$, scalp site, $F(3.01, 141.52) = 213.95$, $p < .001$, $\eta_p^2 = .82$, and their interaction, $F(5.69, 267.53) = 16.23$, $p < .001$, $\eta_p^2 = .26$. To further investigate, we repeated the ANOVA including only the within-subjects factor of vicarious touch type (stroke, hug, handshake, and sitting rest) at each scalp site. The main effect of touch type was statistically significant across most scalp sites, including the prefrontal, $F(2.43, 114.24) = 20.15$, $p < .001$, $\eta_p^2 = .30$, frontal, $F(3, 141) = 32.45$, $p < .001$, $\eta_p^2 = .41$, parietal, $F(2.37, 111.32) = 3.92$, $p = .017$, $\eta_p^2 = .08$, temporal, $F(2.37, 111.14) = 12.48$, $p < .001$, $\eta_p^2 = .21$, and occipital scalp sites, $F(2.49, 117.00) = 21.68$, $p < .001$, $\eta_p^2 = .32$. However, the main effect of vicarious touch type was not significant at central scalp sites, $F(2.13, 100.03) = .43$, $p = .662$, $\eta_p^2 = .01$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.14) revealed that theta activity was significantly higher during all vicarious touches compared to rest at prefrontal, frontal, and occipital scalp sites. This effect was more widespread for vicarious stroking and handshakes, with increased theta at the temporal sites, and at the parietal sites specifically for handshakes. Between touch types, theta activity was significantly higher during vicarious handshakes and hugs compared to stroking. For hugs, this difference was only significant at the prefrontal sites, while for handshakes it was at multiple sites. Additionally, theta activity was significantly greater during handshakes than hugs at the frontal and temporal sites.

Table 5.14. *Post Hoc Pairwise Comparisons with Bonferroni Correction on Log-Transformed Theta Activity Between Touch-Type Conditions (Stroking, Hugging, Handshakes, and Rest) Across Scalp Sites (Prefrontal, Frontal, Central, Parietal, Temporal, and Occipital) for Stroking, Hugging, and Handshakes*

	Prefrontal Theta	**Frontal Theta**	**Central Theta**	**Parietal Theta**	**Temporal Theta**	**Occipital Theta**
Close individuals						
Stroke vs. hug	-.61 (.16)**	-.45 (.12)**	-.48 (.16)*	-.46 (.15)*	-.60 (.15)**	-.26 (.15)

Stroke vs. handshake	-.78 (.19)**	-.61 (.14)**	-.55 (.19)*	-.69 (.20)**	-.67 (.16)**	-.59 (.13)**
Hug vs. handshake	-.17 (.18)	-.17 (.12)	-.07 (.08)	-.23 (.12)	-.07 (.11)	-.33 (.13)
Stroke vs. rest	.75 (.17)**	.13 (.09)	-.12 (.04)*	-.004 (.07)	.05 (.08)	.43 (.08)**
Hug vs. rest	1.36 (.20)**	.58 (.13)**	.36 (.17)	.46 (.17)	.65 (.16)**	.69 (.15)**
Handshake vs. rest	1.53 (.20)**	.75 (.16)**	.43 (.20)	.69 (.22)*	.72 (.16)**	1.02 (.14)**
Strangers						
Stroke vs. hug	-.85 (.18)**	-.36 (.10)**	-.29 (.06)**	-.30 (.08)**	-.46 (.11)**	-.16 (.10)
Stroke vs. handshake	-.93 (.18)**	-.55 (.11)**	-.47 (.09)**	-.53 (.10)**	-.65 (.11)**	-.67 (.10)**
Hug vs. handshake	-.08 (.20)	-.19 (.11)	-.19 (.10)	-.24 (.09)	-.19 (.11)	-.51 (.10)**
Stroke vs. rest	.76 (.18)**	.23 (.13)	.03 (.14)	.14 (.14)	.21 (.14)	.45 (.09)**
Hug vs. rest	1.61 (.20)**	.59 (.12)**	.31 (.14)	.44 (.15)*	.66 (.14)**	.61 (.11)**
Handshake vs. rest	1.69 (.20)**	.78 (.14)**	.50 (.18)*	.68 (.17)**	.85 (.17)**	1.12 (.12)**
Vicarious						
Stroke vs. hug	-.42 (.14)*	.01 (.13)	-.04 (.16)	-.13 (.15)	.03 (.17)	-.23 (.11)
Stroke vs. handshake	-.43 (.10)**	-.55 (.09)**	-.11 (.07)	-.29 (.08)**	-.41 (.09)**	-.32 (.07)**
Hug vs. handshake	-.003 (.13)	-.56 (.11)**	-.07 (.13)	-.16 (.13)	-.44 (.14)*	-.10 (.10)
Stroke vs. rest	.56 (.16)**	.55 (.10)**	.02 (.14)	.14 (.14)	.41 (.12)**	.44 (.10)**
Hug vs. rest	.98 (.19)**	.54 (.13)**	.06 (.13)	-.27 (.14)	.38 (.15)	.66 (.13)**
Handshake vs. rest	.99 (.15)**	1.10 (.11)**	.14 (.13)	.43 (.14)*	.82 (.12)**	.76 (.10)**

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., stroking - hugging). *$p < .05$, **$p < .01$ corrected values.

Theta Key Findings Summary. Overall, theta activity increased across all types of touch (stroking, hugging, handshakes) and all experimental conditions (close individual, stranger, vicarious) relative to baseline across multiple scalp sites, but less so at central sites. Real touch, particularly with strangers, led to more robust and widespread theta activity than vicarious touch. Among all the types of touch, the most significant effects were seen during hugging and handshakes with strangers. No specific effects of touch with close individuals differed from other touch events, suggesting that theta did not seem to signal the prioritised processing of highly affective touch (as would be expected to be experienced during close individual touch) compared to any other touch.

Beta.

Experimental Condition.

Stroking. Analyses on beta activity showed significant main effects for affective forearm stroking in different experimental conditions (close, stranger, vicarious, sitting rest), $F(3, 141) = 9.99$, $p < .001$, $\eta_p^2 = .18$; scalp site, $F(2.98, 140.22) = 75.33$, $p < .001$, $\eta_p^2 = .62$, and their interaction, $F(7.87, 369.64) = 13.50$, $p < .001$, $\eta_p^2 = .22$. To further investigate, we repeated the ANOVA including only the within-subjects factor of experimental condition (close, stranger, vicarious, rest) at each scalp site for stroking. The main effect of experimental condition was statistically significant across the prefrontal, $F(3, 141) = 3.56$, $p = .016$, $\eta_p^2 = .07$, parietal, $F(2.04, 95.95) = 5.33$, $p = .006$, $\eta_p^2 = .10$, temporal, $F(2.44, 114.61) = 36.20$, $p < .001$, $\eta_p^2 = .44$, and occipital scalp sites, $F(3, 141) = 12.91$, $p < .001$, $\eta_p^2 = .22$. However, the main effect of experimental condition was not statistically significant for the frontal scalp site, $F(3, 141) = 2.12$, $p = .101$, $\eta_p^2 = .04$, nor the central scalp site, $F(2.34, 110.11) = 1.71$, $p = .180$, $\eta_p^2 = .04$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.15) revealed significantly higher beta activity during real stroking compared to rest in temporal and occipital scalp sites. Although there was significantly less beta activity during close and vicarious stroking at the parietal scalp site. When comparing stroking across experimental conditions, we found more beta activity during real stroking compared to vicarious stroking at temporal and occipital sites, with the addition of the parietal site for strangers. There was no significant difference in beta activity between stroking from a close individual and stranger.

Hugging. Analyses on beta activity showed significant main effects for hugging in different experimental conditions (close, stranger, vicarious, standing rest), $F(1.83, 86.16)$

= 22.16, $p < .001$, $\eta_p^2 = .32$; scalp site, $F(3.00, 140.74) = 111.87$, $p < .001$, $\eta_p^2 = .70$, and their interaction, $F(6.14, 288.67) = 23.58$, $p < .001$, $\eta_p^2 = .33$. To further investigate, we repeated the ANOVA including only the within-subjects factor of experimental condition (close, stranger, vicarious, rest) at each scalp site for hugs. The main effect of experimental condition was statistically significant at the prefrontal, $F(2.51, 117.99) = 9.77$, $p < .001$, $\eta_p^2 = .17$, parietal, $F(1.50, 70.53) = 5.26$, $p = .013$, $\eta_p^2 = .10$, temporal, $F(1.94, 91.39) = 64.67$, $p < .001$, $\eta_p^2 = .58$, and occipital scalp sites, $F(2.15, 100.89) = 42.68$, $p < .001$, $\eta_p^2 = .48$. However, the main effect of experimental condition was not statistically significant for the frontal, $F(2.03, 95.33) = 1.24$, $p = .293$, $\eta_p^2 = .03$, nor the central scalp sites, $F(1.52, 71.27) = 1.61$, $p = .212$, $\eta_p^2 = .03$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.15) showed significantly higher beta activity during real hugs compared to rest at the prefrontal, temporal, and occipital scalp sites. No significant differences were found between vicarious hugs and rest. Beta activity was also significantly higher during real hugs than vicarious hugs at the temporal and occipital sites, and more widespread for strangers (prefrontal and parietal sites). These differences were unlikely due to posture, as beta activity differences between sitting and standing rest were only significant at the frontal scalp site (refer to Appendix Table C.1). Additionally, hugs with strangers resulted in more beta activity than hugs with close individuals at the temporal site.

Handshakes. Analyses on beta activity showed significant main effects for handshakes in different experimental conditions (close, stranger, vicarious, standing rest), $F(2.19, 102.68) = 30.67$, $p < .001$, $\eta_p^2 = .40$; scalp site, $F(3.39, 159.54) = 112.22$, $p < .001$, $\eta_p^2 = .71$, and their interaction, $F(7.15, 336.14) = 21.02$, $p < .001$, $\eta_p^2 = .31$. To further investigate, we repeated the ANOVA including only the within-subjects factor of experimental condition (close, stranger, vicarious, rest) at each scalp site for handshakes. The main effect of experimental condition was statistically significant across all scalp sites, including prefrontal, $F(3, 141) = 12.30$, $p < .001$, $\eta_p^2 = .21$, frontal, $F(2.39, 112.24) = 4.10$, $p = .014$, $\eta_p^2 = .08$, central, $F(1.95, 91.74) = 4.03$, $p = .022$, $\eta_p^2 = .08$, parietal, $F(1.84, 86.60) = 11.46$, $p < .001$, $\eta_p^2 = .20$, temporal, $F(2.37, 111.28) = 87.95$, $p < .001$, $\eta_p^2 = .65$, and the occipital scalp sites, $F(1.91, 89.78) = 51.14$, $p < .001$, $\eta_p^2 = .52$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.15) showed significantly higher beta activity during real handshakes compared to rest at the prefrontal, temporal, and occipital scalp sites. In contrast, beta activity was significantly lower during vicarious handshakes than rest at the central and parietal sites. Real handshakes also produced significantly more beta activity compared to vicarious handshakes across all scalp sites, with central site differences observed only for strangers. These widespread differences were unlikely due to posture; as beta differences between sitting and standing rest were limited to the frontal sites (refer to Appendix Table C.1). Additionally, handshakes with strangers showed significantly more beta activity than those with close individuals at the temporal and occipital sites.

Table 5.15. *Post Hoc Pairwise Comparisons with Bonferroni Correction on Log-Transformed Beta Activity Between Conditions (Close Individual, Stranger, Vicarious, and Rest) Across Scalp Sites (Prefrontal, Frontal, Central, Parietal, Temporal, and Occipital) for Stroking, Hugging, and Handshakes*

	Prefrontal Beta	**Frontal Beta**	**Central Beta**	**Parietal Beta**	**Temporal Beta**	**Occipital Beta**
Stroking						
Close vs. stranger	.01 (.08)	.07 (.09)	-.04 (.10)	-.08 (.06)	.04 (.08)	.02 (.06)
Close vs. vicarious	.09 (.10)	.20 (.11)	.11 (.09)	.08 (.06)	.82 (.11)**	.23 (.06)**
Stranger vs. vicarious	.08 (.09)	.13 (.10)	.15 (.07)	.16 (.04)**	.79 (.11)**	.21 (.07)*
Close vs. rest	.26 (.10)	.17 (.09)	-.07 (.07)	-.12 (.04)*	.59 (.09)**	.33 (.06)**
Stranger vs. rest	.25 (.09)	.10 (.07)	-.03 (.09)	-.04 (.07)	.55 (.07)**	.31 (.08)**
Vicarious vs. rest	.17 (.08)	-.04 (.09)	-.18 (.08)	-.21 (.06)**	-.23 (.11)	.10 (.06)

Hugging						
Close vs. stranger	-.18 (.09)	-.08 (.06)	-.09 (.06)	-.03 (.06)	-.19 (.07)*	-.11 (.06)
Close vs. vicarious	.20 (.14)	.09 (.13)	.14 (.14)	.30 (.14)	1.14 (.14)**	.65 (.10)**
Stranger vs. vicarious	.38 (.12)*	.17 (.11)	.22 (.11)	.34 (.10)**	1.33 (.16)**	.77 (.10)**
Close vs. rest	.39 (.11)**	-.08 (.11)	.05 (.13)	.16 (.11)	1.02 (.10)**	.67 (.10)**
Stranger vs. rest	.58 (.10)**	.001 (.10)	.14 (.10)	.19 (.07)	1.21 (.12)**	.79 (.10)**
Vicarious vs. rest	.19 (.12)	-.17 (.09)	-.09 (.06)	-.15 (.07)	-.13 (.12)	.02 (.07)
Handshakes						
Close vs. stranger	-.24 (.13)	-.003 (.11)	-.07 (.12)	-.11 (.10)	-.29 (.11)*	-.29 (.10)*
Close vs. vicarious	.37 (.13)*	.37 (.12)*	.34 (.13)	.46 (.12)**	1.32 (.13)**	.77 (.08)**
Stranger vs. vicarious	.61 (.14)**	.37 (.13)*	.42 (.12)**	.57 (.09)**	1.62 (.14)**	1.05 (.12)**
Close vs. rest	.43 (.13)*	.15 (.14)	.05 (.17)	.08 (.14)	1.07 (.11)**	.68 (.09)**
Stranger vs. rest	.68 (.14)**	.16 (.14)	.13 (.14)	.19 (.10)	1.36 (.14)**	.97 (.14)**
Vicarious vs. rest	.06 (.10)	-.22 (.09)	-.29 (.08)**	-.38 (.05)**	-.25 (.09)	-.09 (.07)

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., close – stranger). *p < .05, **p < .01 corrected values.

Touch Type.

Close Individual. Analyses on beta activity showed significant main effects for different touch types (stroking, hugging, handshakes) with a close individual, $F(1.75, 82.05) = 11.91$, $p < .001$, $\eta_p^2 = .20$; scalp site, $F(3.18, 149.64) = 110.41$, $p < .001$, $\eta_p^2 = .70$, and their interaction, $F(4.87, 228.89) = 12.87$, $p < .001$, $\eta_p^2 = .22$. To further investigate, we repeated the ANOVA including only the within-subjects factor of touch type (stroke, hug, handshake, standing rest) at each scalp site for touch shared with close individuals. The main effect of touch type was statistically significant across the prefrontal, $F(3, 141) = 6.03$, $p < .001$, $\eta_p^2 = .11$, temporal, $F(2.34, 109.92) = 60.38$, $p < .001$, $\eta_p^2 = .56$, and occipital scalp sites, $F(2.55, 119.98) = 31.78$, $p < .001$, $\eta_p^2 = .40$. However, the main effect of touch type was not statistically significant at frontal, $F(2.18, 102.55) = 1.56$, $p = .213$, $\eta_p^2 = .03$, central, $F(1.33,$

62.36) = .22, p = .710, η_p^2 = .01, nor parietal scalp sites, F(1.22, 57.53) = 2.36, p = .124, η_p^2 = .05. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.16) revealed significantly higher beta activity during all types of touch with a close individual compared to rest at temporal and occipital scalp sites, and at the prefrontal site for hugs and handshakes. Beta activity was also significantly higher during hugging and handshakes compared to stroking at temporal and occipital sites. These differences were unlikely due to posture; as beta differences between sitting and standing rest were limited to the frontal sites (refer to Appendix Table C.1). No significant differences were found between hugging and handshakes.

Stranger. Analyses on beta activity showed significant main effects for different touch types (stroking, hugging, handshakes) with a stranger, F(1.88, 88.46) = 25.54, p < .001, η_p^2 = .34; scalp site, F(3.28, 153.97) = 121.97, p < .001, η_p^2 = .72, and their interaction, F(8.20, 385.43) = 21.96, p < .001, η_p^2 = .32. To further investigate, we repeated the ANOVA including only the within-subjects factor of touch type (stroke, hug, handshake, standing rest) at each scalp site for touch shared with strangers. The main effect of touch type was statistically significant across the prefrontal, F(2.56, 120.07) = 15.60, p < .001, η_p^2 = .25, parietal, F(1.90, 89.47) = 5.16, p = .008, η_p^2 = .10, temporal, F(2.11, 99.17) = 70.37, p < .001, η_p^2 = .60, and occipital scalp sites, F(2.25, 105.67) = 37.90, p < .001, η_p^2 = .45. However, the main effect of touch type was not significant in frontal, F(1.78, 83.53) = 1.80, p = .175, η_p^2 = .04 nor central scalp sites, F(2.10, 98.64) = 1.04, p = .362, η_p^2 = .02. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.16) showed significantly higher beta activity during all touches with strangers compared to rest at temporal and occipital scalp sites, and at the prefrontal site for hugs and handshakes. Beta activity was also significantly higher during stranger hugging and handshakes compared to stroking at prefrontal, temporal, and occipital scalp sites, with an additional increase at the parietal site for hugs. These differences were unlikely due to posture, as beta differences between sitting and standing rest were limited to frontal sites (see Appendix Table C.1). No significant differences were found between hugging and handshakes.

Vicarious. Analyses on beta activity showed that the main effect for vicarious touch types (stroking, hugging, handshakes) was not statistically significant, *F*(3, 141) = 2.16, $p = .096$, $\eta_p^2 = .04$. Although significant main effects were found for scalp site, *F*(3.16, 148.47) = 64.48, $p < .001$, $\eta_p^2 = .58$, and the interaction between touch type and scalp site, *F*(6.63, 311.56) = 5.76, $p < .001$, $\eta_p^2 = .11$. To further investigate, we repeated the ANOVA including only the within-subjects factor of vicarious touch type (stroke, hug, handshake, sitting rest) at each scalp site. The main effect of touch type was statistically significant at the prefrontal, *F*(2.09, 98.09) = 4.23, $p = .016$, $\eta_p^2 = .08$, central, *F*(2.18, 102.59) = 5.33, $p = .005$, $\eta_p^2 = .10$, and parietal scalp sites, *F*(2.22, 104.39) = 12.90, $p < .001$, $\eta_p^2 = .22$. However, the main effect of vicarious touch type was not significant at frontal, *F*(3, 141) = .14, $p = .935$, $\eta_p^2 = .003$, temporal, *F*(3, 141) = 2.21, $p = .093$, $\eta_p^2 = .05$, nor occipital scalp sites, *F*(2.31, 108.54) = 1.96, $p = .139$, $\eta_p^2 = .04$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.16) revealed significantly lower beta activity during vicarious stroking and handshakes compared to rest at the parietal site, and at the central site for vicarious handshakes. Furthermore, beta activity was significantly lower during vicarious handshakes compared to stroking and hugs at the parietal site. No significant differences were found between vicarious hugs and stroking or rest.

Table 5.16. *Post Hoc Pairwise Comparisons with Bonferroni Correction on Log-Transformed Beta Activity Between Touch-Type Conditions (Stroking, Hugging, Handshakes,*

and Rest) Across Scalp Sites (Prefrontal, Frontal, Central, Parietal, Temporal, and Occipital) for Touch Shared with Close Individuals, Strangers, and Vicarious

	Prefrontal Beta	**Frontal Beta**	**Central Beta**	**Parietal Beta**	**Temporal Beta**	**Occipital Beta**
Close individuals						
Stroke vs. hug	-.22 (.12)	.07 (.10)	-.09 (.13)	-.27 (.12)	-.47 (.08)**	-.42 (.08)**
Stroke vs. handshake	-.27 (.13)	-.16 (.13)	-.09 (.17)	-.20 (.15)	-.52 (.10)**	-.43 (.08)**
Hug vs. handshake	-.04 (.11)	-.23 (.08)	-.00 (.07)	.08 (.05)	-.06 (.08)	-.004 (.08)
Stroke vs. rest	.17 (.11)	-.01 (.10)	-.04 (.06)	-.12 (.04)	.55 (.08)**	.25 (.06)**
Hug vs. rest	.39 (.11)**	-.08 (.11)	.05 (.13)	.16 (.11)	1.02 (.10)**	.67 (.10)**
Handshake vs. rest	.43 (.13)*	.15 (.14)	.05 (.17)	.08 (.14)	1.07 (.11)**	.68 (.09)**
Strangers						
Stroke vs. hug	-.41 (.11)**	-.08 (.09)	-.13 (.09)	-.22 (.06)**	-.69 (.09)**	-.56 (.09)**
Stroke vs. handshake	-.52 (.13)**	-.24 (.13)	-.12 (.11)	-.22 (.08)	-.85 (.12)**	-.74 (.11)**
Hug vs. handshake	-.10 (.11)	-.15 (.08)	.01 (.09)	.002 (.06)	-.16 (.10)	-.18 (.11)
Stroke vs. rest	.16 (.11)	-.08 (.08)	.003 (.09)	-.03 (.06)	.51 (.07)**	.23 (.08)*
Hug vs. rest	.58 (.10)**	.001 (.10)	.14 (.10)	.19 (.07)	1.21 (.12)**	.79 (.10)**
Handshake vs. rest	.68 (.14)**	.16 (.14)	.13 (.14)	.19 (.10)	1.36 (.14)**	.97 (.14)**
Vicarious						
Stroke vs. hug	-.11 (.07)	-.05 (.08)	-.06 (.08)	-.05 (.07)	-.15 (.10)	-.001 (.06)
Stroke vs. handshake	.02 (.06)	.001 (.11)	.15 (.07)	.18 (.04)**	-.03 (.09)	.11 (.05)
Hug vs. handshake	.13 (.06)	.05 (.09)	.20 (.10)	.24 (.07)*	.12 (.10)	.11 (.04)
Stroke vs. rest	.17 (.08)	-.04 (.09)	-.18 (.08)	-.21 (.06)**	-.23 (.11)	.10 (.06)
Hug vs. rest	.28 (.11)	.02 (.09)	-.12 (.06)	-.15 (.07)	-.09 (.12)	.10 (.08)
Handshake vs. rest	.15 (.10)	-.04 (.11)	-.32 (.10)*	-.39 (.06)**	-.21 (.11)	-.01 (.07)

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., stroking - hugging). *$p < .05$, **$p < .01$ corrected values.

Beta Key Findings Summary. Similar to theta, beta activity was significantly higher during real touch compared to rest and vicarious touch, particularly in parietal, temporal, and occipital scalp sites. The most significant and widespread effects were observed during hugs and handshakes with strangers, extending to prefrontal sites for hugs, and to all scalp sites for handshakes. No specific effects of touch with close individuals differed from other touch events, suggesting no differences in beta power that signal prioritised processing of more affective touch. However, unlike theta, vicarious touch resulted in less beta activity than rest.

Alpha.

Experimental Condition.

Stroking. Analyses on alpha activity showed significant main effects for affective forearm stroking in different experimental conditions (close, stranger, vicarious, sitting rest), $F(2.16, 101.71) = 6.03$, $p = .003$, $\eta_p^2 = .11$; scalp site, $F(2.95, 138.82) = 132.97$, $p < .001$, $\eta_p^2 = .74$, and their interaction, $F(5.58, 262.05) = 12.19$, $p < .001$, $\eta_p^2 = .21$. To further investigate, we repeated the ANOVA including only the within-subjects factor of experimental condition (close, stranger, vicarious, rest) at each scalp site for stroking. The main effect of experimental condition was statistically significant across prefrontal, $F(3, 141) = 4.47$, $p = .005$, $\eta_p^2 = .09$, central, $F(1.64, 76.86) = 9.69$, $p < .001$, $\eta_p^2 = .17$, parietal, $F(1.77, 83.11) = 13.36$, $p < .001$, $\eta_p^2 = .22$, temporal, $F(1.95, 91.81) = 4.93$, $p = .010$, $\eta_p^2 = .10$, and the occipital scalp site, $F(2.40, 112.71) = 7.91$, $p < .001$, $\eta_p^2 = .14$. However, the main effect of experimental condition was not statistically significant for the frontal scalp site, $F(2.34, 109.93) = 1.50$, $p = .226$, $\eta_p^2 = .03$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.17) revealed significantly lower alpha activity during all stroking compared to rest at the parietal scalp site, and this effect was more widespread for close individual (central site) and vicarious stroking (central and occipital scalp sites). When comparing between experimental conditions, alpha activity was significantly lower during vicarious than real stroking at prefrontal and occipital sites, with more widespread effect for strangers (parietal and temporal sites). No differences in alpha activity were found between stroking from close individuals and strangers.

Hugging. Analyses on alpha activity showed significant main effects for hugs in different experimental conditions (close, stranger, vicarious, standing rest), *F*(2.24, 105.37) = 9.25, $p < .001$, $\eta_p^2 = .16$; scalp site, *F*(2.64, 124.26) = 140.87, $p < .001$, $\eta_p^2 = .75$, and their interaction, *F*(5.58, 262.13) = 12.53, $p < .001$, $\eta_p^2 = .21$. To further investigate, we repeated the ANOVA including only the within-subjects factor of experimental condition (close, stranger, vicarious, rest) at each scalp site for hugging. The main effect of experimental condition was statistically significant across all scalp sites, including prefrontal, *F*(3, 141) = 15.38, $p < .001$, $\eta_p^2 = .25$, frontal, *F*(2.21, 103.92) = 4.34, $p = .013$, $\eta_p^2 = .09$, central, *F*(1.88, 88.18) = 4.59, $p = .014$, $\eta_p^2 = .09$, parietal, *F*(2.20, 103.24) = 7.38, $p < .001$, $\eta_p^2 = .14$, temporal, *F*(2.02, 95.06) = 8.80, $p < .001$, $\eta_p^2 = .16$, and the occipital scalp sites, *F*(2.44, 114.52) = 18.06, $p < .001$, $\eta_p^2 = .28$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.17) revealed that alpha activity was significantly higher during real hugs compared to rest at the prefrontal scalp site, and temporal site for strangers. In contrast, alpha activity was significantly lower during vicarious hugs than rest at central, parietal, and occipital sites. Differences at parietal and occipital sites may be due to higher alpha activity during standing rest compared to sitting rest, as participants were sitting during vicarious stroking (see Appendix Table C.1). However, the difference at central sites is unlikely to be posture-related, as no difference in alpha activity was found between sitting and standing rest at this site. Alpha activity during real hugs was also significantly higher than vicarious hugs at prefrontal, temporal, and occipital sites, with more widespread effects for strangers (frontal and parietal sites). Since only of the prefrontal site showed no posture-related differences, these findings should be interpreted with caution. No significant differences in alpha activity were found between hugs with close individuals and strangers.

Handshakes. Analyses on alpha activity showed significant main effects for handshakes in different experimental conditions (close, stranger, vicarious, standing rest), $F(2.19, 102.80) = 8.68$, $p < .001$, $\eta_p^2 = .16$; scalp site, $F(3.20, 150.44) = 162.53$, $p < .001$, $\eta_p^2 = .78$, and their interaction, $F(6.76, 317.86) = 14.37$, $p < .001$, $\eta_p^2 = .23$. To further investigate, we repeated the ANOVA including only the within-subjects factor of experimental condition (close, stranger, vicarious, rest) at each scalp site for handshakes. The main effect of experimental condition was statistically significant across the prefrontal, $F(3, 141) = 16.21$, $p < .001$, $\eta_p^2 = .26$, central, $F(1.59, 74.88) = 7.04$, $p = .003$, $\eta_p^2 = .13$, parietal, $F(1.89, 88.72) = 9.87$, $p < .001$, $\eta_p^2 = .17$, temporal, $F(2.19, 103.13) = 10.11$, $p < .001$, $\eta_p^2 = .18$, and occipital scalp sites, $F(2.11, 99.14) = 13.27$, $p < .001$, $\eta_p^2 = .22$. However, experimental condition was not significant at frontal scalp sites, $F(2.54, 119.42) = 1.46$, $p = .234$, $\eta_p^2 = .03$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.17) revealed significantly higher prefrontal alpha activity during real handshakes compared to rest. In contrast, alpha activity was significantly lower during vicarious handshakes compared to rest at central, parietal, temporal, and occipital sites. Similar to stroking and hugs, alpha activity was significantly higher for real handshakes at prefrontal, temporal, and occipital sites, and more widespread for strangers (central and parietal sites). However, caution is needed when interpreting comparisons with vicarious handshakes, as alpha activity was significantly higher during standing rest than sitting rest at the frontal, parietal, temporal, and occipital scalp sites (see Appendix Table C.1). No significant differences in alpha activity were found between handshakes with close individuals and strangers.

Table 5.17. *Post Hoc Pairwise Comparisons with Bonferroni Correction on Log-Transformed Alpha Activity Between Conditions (Close Individual, Stranger, Vicarious, and*

Rest) Across Scalp Sites (Prefrontal, Frontal, Central, Parietal, Temporal, and Occipital) for Stroking, Hugging, and Handshakes

	Prefrontal Alpha	**Frontal Alpha**	**Central Alpha**	**Parietal Alpha**	**Temporal Alpha**	**Occipital Alpha**
Stroking						
Close vs. stranger	-.01 (.10)	-.03 (.07)	-.14 (.12)	-.13 (.10)	-.11 (.08)	-.05 (.07)
Close vs. vicarious	.29 (.10)*	.03 (.07)	-.01 (.11)	.05 (.11)	.17 (.07)	.27 (.09)*
Stranger vs. vicarious	.30 (.10)*	.06 (.06)	.14 (.05)	.18 (.06)*	.28 (.05)**	.32 (.08)**
Close vs. rest	.23 (.11)	-.12 (.06)	-.50 (.08)**	-.56 (.09)**	-.05 (.06)	-.19 (.11)
Stranger vs. rest	.24 (.11)	-.09 (.09)	-.36 (.14)	-.44 (.13)*	.06 (.10)	-.14 (.10)
Vicarious vs. rest	-.06 (.11)	-.14 (.09)	-.50 (.13)**	-.61 (.14)**	-.22 (.09)	-.46 (.12)**
Hugging						
Close vs. stranger	-.19 (.14)	.01 (.05)	.04 (.07)	-.03 (.08)	-.04 (.06)	.07 (.07)
Close vs. vicarious	.56 (.17)**	.30 (.12)	.38 (.17)	.42 (.17)	.52 (.16)*	.82 (.13)**
Stranger vs. vicarious	.76 (.15)**	.29 (.11)*	.34 (.15)	.45 (.14)*	.57 (.15)**	.75 (.12)**
Close vs. rest	.64 (.15)**	.03 (.10)	-.11 (.16)	-.24 (.17)	.28 (.12)	.30 (.14)
Stranger vs. rest	.83 (.14)**	.02 (.09)	-.14 (.13)	-.21 (.14)	.32 (.11)*	.22 (.13)
Vicarious vs. rest	.07 (.15)	-.27 (.11)	-.49 (.12)**	-.66 (.15)**	-.24 (.13)	-.53 (.14)**
Handshakes						
Close vs. stranger	-.26 (.17)	-.10 (.10)	-.09 (.11)	-.06 (.12)	-.21 (.09)	-.21 (.09)
Close vs. vicarious	.59 (.14)**	.13 (.10)	.26 (.12)	.36 (.14)	.42 (.10)**	.59 (.11)**
Stranger vs. vicarious	.85 (.15)**	.22 (.10)	.35 (.10)**	.42 (.11)**	.62 (.12)**	.80 (.12)**
Close vs. rest	.56 (.15)**	-.03 (.13)	-.37 (.20)	-.45 (.21)	.14 (.14)	.01 (.17)
Stranger vs. rest	.82 (.16)**	.07 (.12)	-.28 (.16)	-.39 (.17)	.35 (.14)	.22 (.17)
Vicarious vs. rest	-.03 (.11)	-.15 (.09)	-.63 (.11)**	-.81 (.13)**	-.27 (.10)*	-.58 (.13)**

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., close – stranger). *$p < .05$, **$p < .01$ corrected values.

Touch Type.

Close Individual. Analyses on alpha activity showed significant main effects for different touch types (stroking, hugging, handshakes) with a close individual, $F(1.67, 78.25) = 6.08$, $p = .006$, $\eta_p^2 = .12$; scalp site, $F(3.06, 143.81) = 146.53$, $p < .001$, $\eta_p^2 = .76$, and their interaction, $F(5.08, 238.94) = 9.27$, $p < .001$, $\eta_p^2 = .17$. To further investigate, we repeated the ANOVA including only the within-subjects factor of touch type (stroke, hug, handshake, standing rest) at each scalp site for touch shared with close individuals. The main effect of touch type was statistically significant across all scalp sites, including the prefrontal, $F(2.62, 122.94) = 10.70$, $p < .001$, $\eta_p^2 = .19$, frontal, $F(1.74, 81.63) = 4.40$, $p = .019$, $\eta_p^2 = .09$, central, $F(1.33, 62.60) = 5.27$, $p = .017$, $\eta_p^2 = .10$, parietal, $F(1.49, 69.95) = 6.64$, $p = .005$, $\eta_p^2 = .12$, temporal, $F(1.58, 74.13) = 5.89$, $p = .008$, $\eta_p^2 = .11$, and the occipital scalp sites, $F(2.51, 117.89) = 7.93$, $p < .001$, $\eta_p^2 = .14$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.18) showed that alpha activity was significantly higher during hugs and handshakes with close individuals compared to rest at prefrontal scalp sites. In contrast, alpha activity was significantly lower during stroking than rest at frontal, central, parietal, and occipital sites. Alpha activity was also higher during hugs and handshakes than stroking with close individuals at prefrontal sites, with hugs influencing all scalp sites. Additionally, hugging showed higher alpha activity than handshakes at the central site. However, these comparisons should be interpreted with caution, as alpha activity was higher during standing rest (the comparison condition) than sitting rest (when stroking occurred) at the frontal, parietal, temporal, and occipital scalp sites (see Appendix Table C.1).

Stranger. Analyses on alpha activity showed significant main effects for different touch types (stroking, hugging, handshakes) with a stranger, $F(1.93, 90.54) = 7.85$, $p < .001$, $\eta_p^2 = .14$; scalp site, $F(2.98, 139.99) = 141.78$, $p < .001$, $\eta_p^2 = .75$, and their interaction, $F(6.78, 318.56) = 15.00$, $p < .001$, $\eta_p^2 = .24$. To further investigate, we repeated the ANOVA including only the within-subjects factor of touch type (stroke, hug, handshake, standing rest) at each scalp site for touch shared with strangers. The main effect of touch type was statistically significant across all scalp sites, including the prefrontal, $F(3, 141) = 22.06$, $p < .001$, $\eta_p^2 = .32$, frontal, $F(2.07, 97.12) = 5.88$, $p = .004$, $\eta_p^2 = .11$, central, $F(1.72, 80.99) = 4.42$, $p = .019$, $\eta_p^2 = .09$, parietal, $F(1.73, 81.38) = 7.45$, $p = .002$, $\eta_p^2 = .14$, temporal, $F(1.96, 91.98) = 8.26$, $p < .001$, $\eta_p^2 = .15$, and the occipital scalp sites, $F(2.29, 107.69) = 7.80$, $p < .001$, $\eta_p^2 = .14$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.18) revealed higher alpha activity during stranger hugs and handshakes compared to rest at the prefrontal site, and at the temporal site for hugs. In contrast, significantly lower alpha activity was found during stranger stroking than rest at frontal, central, parietal, and occipital sites. Alpha activity was also significantly higher during hugs and handshakes than stroking at prefrontal, frontal, temporal, and occipital scalp sites, and more widespread for hugs (central and parietal sites). No significant alpha differences were found between hugging and handshakes. However, stranger stroking comparisons should be interpreted with caution, as alpha activity during standing rest was significantly higher than sitting rest, except for prefrontal and central sites (see Appendix Table C.1).

Vicarious. Analyses on alpha activity showed significant main effects for vicarious touch types (stroking, hugging, handshakes), $F(2.19, 102.73) = 5.06$, $p = .006$, $\eta_p^2 = .10$; scalp site, $F(3.45, 162.05) = 141.93$, $p < .001$, $\eta_p^2 = .75$, and their interaction, $F(6.12, 287.57) = 17.28$, $p < .001$, $\eta_p^2 = .27$. To further investigate, we repeated the ANOVA including only the within-subjects factor of vicarious touch type (stroke, hug, handshake, sitting rest) at each scalp site. The main effect of touch type was statistically significant across the central, $F(2.13, 100.24) = 11.15$, $p < .001$, $\eta_p^2 = .19$, parietal, $F(2.17, 101.99) = 14.85$, $p < .001$, $\eta_p^2 = .24$, and the occipital scalp sites, $F(1.71, 80.56) = 8.21$, $p = .001$, $\eta_p^2 = .15$. However, the main effect of vicarious touch type was not significant at the prefrontal,

$F(2.08, 97.95) = 2.35$, $p = .099$, $\eta_p^2 = .05$, frontal, $F(2.34, 110.18) = 1.66$, $p = .189$, $\eta_p^2 = .03$, and temporal scalp sites, $F(2.31, 108.33) = 1.88$, $p = .152$, $\eta_p^2 = .04$. Post hoc pairwise comparisons with Bonferroni correction (see Table 5.18) revealed significantly lower alpha activity during all vicarious touches compared to rest at central and parietal scalp sites, and the occipital site for stroking and handshakes. Alpha activity was also significantly lower during vicarious stroking than vicarious handshakes at the frontal site. No other significant differences were found between vicarious touches.

Table 5.18. *Post Hoc Pairwise Comparisons with Bonferroni Correction on Log-Transformed Alpha Activity Between Touch-Type Conditions (Stroking, Hugging, Handshakes, and Rest) Across Scalp Sites (Prefrontal, Frontal, Central, Parietal, Temporal, and Occipital) for Touch Shared with Close Individuals, Strangers, and Vicarious*

	Prefrontal Alpha	**Frontal Alpha**	**Central Alpha**	**Parietal Alpha**	**Temporal Alpha**	**Occipital Alpha**
Close individuals						
Stroke vs. hug	-.54 (.13)**	-.32 (.10)**	-.43 (.15)*	-.42 (.15)*	-.43 (.10)**	-.65 (.13)**
Stroke vs. handshake	-.46 (.15)*	-.26 (.12)	-.16 (.19)	-.21 (.18)	-.29 (.12)	-.37 (.14)
Hug vs. handshake	.08 (.14)	.06 (.07)	.27 (.08)*	.21 (.09)	.14 (.07)	.29 (.12)
Stroke vs. rest	.10 (.11)	-.29 (.06)**	-.53 (.07)**	-.66 (.09)**	-.15 (.06)	-.36 (.11)*
Hug vs. rest	.64 (.15)**	.03 (.10)	-.11 (.16)	-.24 (.17)	.28 (.12)	.30 (.14)
Handshake vs. rest	.56 (.15)**	-.03 (.13)	-.37 (.20)	-.45 (.21)	.14 (.14)	.01 (.17)
Strangers						
Stroke vs. hug	-.72 (.12)**	-.28 (.06)**	-.25 (.06)**	-.32 (.07)**	-.36 (.07)**	-.53 (.10)**
Stroke vs. handshake	-.71 (.14)**	-.33 (.09)**	-.11 (.09)	-.14 (.09)	-.39 (.10)**	-.53 (.13)**
Hug vs. handshake	.01 (.14)	-.05 (.07)	.14 (.08)	.18 (.09)	-.03 (.08)	.001 (.12)
Stroke vs. rest	.11 (.11)	-.26 (.08)*	-.39 (.13)*	-.53 (.13)**	-.04 (.10)	-.31 (.11)*
Hug vs. rest	.83 (.14)**	.02 (.09)	-.14 (.13)	-.21 (.14)	.32 (.11)*	.22 (.13)
Handshake vs. rest	.82 (.16)**	.07 (.12)	-.28 (.16)	-.39 (.17)	.35 (.14)	.22 (.17)
Vicarious						

Stroke vs. hug	-.27 (.10)	-.05 (.08)	-.04 (.13)	-.05 (.12)	-.07 (.12)	-.10 (.07)
Stroke vs. handshake	-.16 (.07)	-.16 (.05)*	.11 (.05)	.11 (.06)	-.04 (.06)	-.05 (.06)
Hug vs. handshake	.11 (.09)	-.12 (.08)	.15 (.11)	.16 (.10)	.03 (.10)	.05 (.07)
Stroke vs. rest	-.06 (.11)	-.14 (.09)	-.50 (.13)**	-.61 (.14)**	-.22 (.09)	-.46 (.12)**
Hug vs. rest	.21 (.15)	-.10 (.11)	-.45 (.12)**	-.56 (.14)**	-.15 (.12)	-.36 (.14)
Handshake vs. rest	.10 (.12)	.02 (.09)	-.60 (.12)**	-.72 (.13)**	-.18 (.09)	-.41 (.13)*

Note. Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., stroking - hugging). *$p < .05$, **$p < .01$ corrected values.

Alpha Key Findings Summary. These findings should be interpreted with caution, as increased alpha activity may be influenced by posture differences; participants were seated during vicarious touch and stroking, while standing during real interactions, and we found lower alpha activity during sitting than standing rest at frontal, parietal, temporal and occipital scalp sites. Similar to theta and beta, real hugs and handshakes showed significantly higher alpha activity compared to rest and vicarious touch, with greater effects for hugs. As seen in beta, alpha activity was significantly lower during vicarious touch than rest. Additionally, stroking revealed lower alpha than rest across experimental conditions. No specific effects of touch with close individuals differed from touch with strangers, suggesting no differences in alpha power that signal prioritised processing of more affective touch.

Discussion

Research highlights the protective role of tactile interactions against stress (Dagnino-Subiabre, 2022; Fishman et al., 1995; Kidd et al., 2023) and their benefits for physical health (Field, 2010; Packheiser et al., 2023; Thomas & Kim, 2021). Older adults tend to perceive touch as more emotionally meaningful and pleasant than younger adults (Guest et al., 2014; Sehlstedt et al., 2016), yet they engage in less frequent touch (Upenieks & Schafer, 2022). This study sought to contribute to the growing body of research by examining the characteristics of touch behaviours reported over a four-month period in an older adult sample. Additionally, we investigated how touch frequency relates to cognitive performance and physiological stress responses (HR and HRV) during a stress-inducing task. Moreover, we explored whether pleasantness ratings and electrophysiological responses (HR, HRV, and EEG) varied based on the type of touch (stroking, hugging, handshakes) and the nature of the interaction (with close individuals, strangers, or vicariously experienced) in this older adult population.

Longitudinal Survey

We found that older adults living with others and in higher-quality relationships engaged in more frequent partner touch, consistent with research showing that cohabitation and marriage increases physical contact compared to living alone (McDaniel & Andersen, 1998; Trotter et al., 2018), while trust and happiness in relationships promote touch more than conflict and dissatisfaction (Debrot et al., 2013; Jakubiak et al., 2021). Additionally, individuals with a greater desire for social touch reported more touch with non-partners, suggesting that older adults with a natural affinity for touch actively seek out physical closeness in broader social contexts.

Over the four-month period, romantic partner touch, especially hugging, was most frequent and consistently rated as the most pleasant. This echoes findings that partners are touched more often and with greater valence and arousal than others (Beßler et al., 2020; Xu et al., 2023), likely because couples express emotional support and affection through physical touch (Grewen et al., 2005; M. Diamond, 2000). Partner touch is also most strongly associated with physiological and psychological benefits, such as reduced blood pressure during handholding and hugging (Grewen et al., 2003), lower cortisol after massages (Ditzen et al., 2007), decreased anxiety (Coan et al., 2006), and reduced neuroendocrine stress (Navyte et al., 2024). Earlier research found that young adults engage more in cuddling/holding than hugging in romantic relationships, with women also engaging in more handholding than hugging

(Gulledge et al., 2003), indicating that while patterns of romantic touch being the most frequent and pleasant persist into older age, there may be age-related changes in touch type preferences. Furthermore, we found that among non-romantic relationships, family members and friends were most frequently touched, especially through hugs, reflecting the role of hugs in close interpersonal relationships. Touches with colleagues, neighbours, and acquaintances were less frequent and rated less pleasant, likely reflecting the more formal nature of these relationships, consistent with findings that closer relationships elicit more positive emotional responses to touch (Suvilehto et al., 2015).

In terms of satisfaction with the amount of touch they received, participants consistently reported dissatisfaction with the quantity shared with both romantic partners and non-partners. This dissatisfaction persisted over time and was stronger for romantic partners, suggesting that even when touch occurs frequently, participants desired more. This echoes findings during COVID-19, where prolonged social distancing increased the desire for intimate touch (kissing, hugging, caressing from partner or close family), even when it was already occurring more than other touches (Von Mohr et al., 2021a). This may indicate a broader trend of a need for greater physical or emotional connection.

Both long-term and short-term touch frequency reports demonstrated general stability over time, with long-term reports being more consistent than short-term reports, indicating stable reporting patterns of retrospective touch frequency over extended periods (e.g., 12 months). In contrast, short-term reports exhibited greater variability, likely reflecting daily fluctuations influenced by situational factors such as interpersonal conflict, which can reduce opportunities for touch from one month to another (Bolger et al., 1989; Rook, 2001). However, perceived relationship quality (PRQC) did not change over three months, suggesting that this could be a result of more trivial factors, such as more or less presence due to work/travel in one month compared to the next. Additionally, each time participants reported touch frequency over the past 12 months, they may have recalled their previous responses and repeated them for consistency (Pyszczynski et al., 1985).

Moreover, short-term reports indicated more frequent touch with both partners and non-partners compared to long-term reports. This increased frequency and variability in short-term reports may partly result from more fine-grained response options, allowing for more precise reporting than the broader averages captured in long-term reports. Additionally, the long-term scale's lowest frequency option is “Several times a week,” which does not capture higher frequencies like “per day” or “per hour.” Moreover, individuals may be reluctant to select the extreme scale endpoints (Nye et al., 2010; Scheier & Carver, 1985). While long-term reports showed greater consistency for touch with partners than with non-partners, short-term reports of touch with partners were slightly less stable than those with non-partners, although the difference was less pronounced than in long-term reports. These findings suggest that longitudinal surveys, such as the National Social Life Health and Aging Project (NSHAP), which rely on long-term retrospective reports, may accurately capture stable partner touch patterns but may underrepresent touch frequency and oversimplify touch dynamics. Including short-term reports, and fine-grained response options could address this gap by capturing more precise and variable short-term touch patterns to accompany long-term touch frequency reports.

Stroop Task

Contrary to expectations, we found that more touch shared with romantic partners or non-partners over a four-month period, did not improve cognitive control (accuracy or reaction time (RT)) nor modulate cardiovascular responses (heart rate (HR) or heart rate variability (HRV)) during the Stroop task. This task measures cognitive control (MacLeod, 1991; Norman & Shallice, 2000; Stroop, 1935) and psychological stress (Šiška, 2002) by requiring participants to inhibit automatic responses and adapt to conflicting information (e.g., naming the colour of a word when the word itself represents a different colour). This cognitive conflict induces stress, which is typically measured through changes in HR (Mathewson et al., 2010; Mueller et al., 2022; Waldstein et al., 1997) and HRV (Grillot et al., 1995; Satish et al., 2015; Šiška, 2002).

While participants exhibited an increase in HR during the Stroop task, reflecting a physiological stress response, prior touch did not affect cardiovascular responses to stress. We also did not find significant differences in HRV between rest and the Stroop task. Existing research indicates that touch during cognitive tasks improves cognitive control (e.g., handholding improves error-related neural monitoring and inhibitory control; Saunders et al., 2018), and touch during stressful tasks reduces HR (e.g., wrist touch during a cold pressor task; Drescher et al., 1985). Touch administered before a stressful task can also promote resilience (e.g., partner massage before a stress task lowers cortisol and HR; Ditzen et al., 2007). This suggests that touch may mitigate cardiovascular stress responses when administered during or immediately before stressful tasks. However, habitual touch over time may not accumulate to improve cognitive control or acute cardiovascular responses. Its effects appear more context-dependent, with immediate, intentional touch providing direct calming effects, while long-term touch frequency may influence chronic stress regulation, as indicated by associations between 12-month touch frequency and lower neuroendocrine stress (Navyte et al., 2024).

Experimental Touch Pleasantness

We hypothesised that both stroking and hugging, whether with close individuals or strangers, would be rated as most pleasant, with touch from close individuals rated more highly than from strangers. We also expected vicarious touches to be rated as less pleasant than real touches. As anticipated, hugging close individuals was rated the most pleasant, followed by stroking from close individuals, and by stroking and hugging strangers.

Vicarious touches were rated lower overall, though vicarious hugging was the most pleasant among them. These results are consistent with the longitudinal survey, where participants also rated hugging partners as the most pleasant, followed by hugging family and friends. This aligns with previous research showing that hugs from close individuals provide emotional support and help buffer stress (Cohen et al., 2015; Light et al., 2005; van Raalte & Floyd, 2021) and are generally rated positively (Floyd, 1999). Hugs with strangers, however, were rated as less pleasant than those with close individuals, and also less pleasant relative to vicarious hugs.

Contrary to our expectations, there was no significant difference in the pleasantness of stroking between close individuals and strangers. This suggests that the pleasantness of stroking may be less influenced by the relationship between the individuals, unlike hugs, which are perceived as significantly more pleasant when shared with close individuals. Previous research on CT-optimal stroking supports this, showing that stroking can be rated as pleasant even when delivered by a tactile stimulator (Ackerley, Backlund Wasling, et al., 2014; Triscoli, Croy, Steudte-Schmiedgen, et al., 2017). This implies that the activation of CT-fibres may be primarily responsible for the pleasantness of stroking, whereas the emotional context or relationship seems more critical for pleasantness of hugs.

Handshakes were rated as pleasant but less so than other forms of touch, regardless of the relationship with the person. While handshakes are often associated with conveying interpersonal trust (Burgoon, 1991), they are more closely linked to personality traits such as extraversion and dominance (Åström, 1994; Chaplin et al., 2000) than to affective communication. Additionally, vicarious touches were rated as the least pleasant overall, suggesting that although vicarious touch can activate neural representations similar to direct touch (Bufalari & Ionta, 2013; Keysers & Gazzola, 2009) and has been rated as pleasant in previous studies (Kirsch et al., 2024; Pawling et al., 2024), it did not evoke the same subjective sense of pleasantness as real touch. Notably, among vicarious touches, vicarious hugs were rated as the most pleasant, implying that empathetic responses to hugs may generate higher levels of perceived pleasantness than other vicarious touches. Perhaps vicarious touch can emotionally remind individuals of real touch, though its effects appear to vary by touch type. For example, while vicarious hugs were rated as the most pleasant among vicarious touch types, vicarious stroking did not evoke similar pleasantness.

HR and HRV

We examined how different types of touch (stroking, hugging, and handshakes) under different experimental conditions (close individual, stranger, and vicarious) influenced HR and HRV. Our hypotheses were that real stroking and hugging, especially with close individuals, would lead to more of a reduction in HR and increase in HRV compared to vicarious touch, and that handshakes would not significantly affect HR and HRV.

In line with our hypotheses, we found that both real and vicarious stroking consistently reduced HR. This finding supports prior research showing that slow, CT-optimal stroking can reduce HR in both adults and infants (Fairhurst et al., 2014; Pawling et al., 2017; Triscoli, Croy, Olausson, et al., 2017). However, contrary to expectations, HR reductions were similar regardless of whether the stroking was administered by a close individual, a stranger, or even observed vicariously. This suggests that the calming effect of stroking is largely independent of the identity of the person delivering the touch and even whether the touch is real or observed. Even though subjective pleasantness ratings were significantly higher for real stroking than vicarious, this did not seem to effect HR response. This may reflect the universally soothing qualities of CT-optimal stroking (Björnsdotter & Olausson, 2011; Haggarty et al., 2021). Our study is among the first to demonstrate that HR reductions occur equally across these touch conditions, suggesting a possible application in clinical practice and elderly care.

Unexpectedly, we found that stranger handshakes increased HR, contrary to our expectation that handshakes would not affect HR. This increase may be due to the formal, less intimate nature of handshakes, especially with strangers, which may induce tension in the experimental setting (Åström, 1993; Nagy et al., 2020). In contrast, vicarious handshakes and hugs led to a decrease in HR compared to rest or real touch. This effect, however, is likely due to posture differences, as participants were seated during vicarious touches but standing during real touches. We found that HR was significantly higher during standing than sitting rest, which likely explains this HR reduction during vicarious touch.

For HRV, our hypothesis that real stroking and hugging, particularly with close individuals, would increase HRV, was only partially supported. We found that real hugs did elevate HRV, suggesting increased parasympathetic activity and relaxation (Dreisoerner et al., 2021; Light et al., 2005; Yoshida et al., 2020). This is consistent with previous research showing that tactile stimulation, such as hugs or massage, increases vagus nerve activity in a pressure-based process and leads to lower autonomic nervous system activation (Ferrell-Torry & Glick., 1993; Field., 1998). However, HRV was only significantly higher than rest during hugs with close individuals, whereas HRV during stranger hugs was higher than vicarious hugs, but not higher than rest. This indicates that emotional closeness likely plays a role in activating the parasympathetic nervous system during hugs with emotionally close individuals, as seen in HRV increase during infant-parent hugs but not during infant-stranger hugs (Yoshida et al., 2020), but also in reduced cortisol levels during stranger hugs, but not HR differences (Dreisoerner et al., 2021).

Interestingly, vicarious touches, particularly vicarious stroking and hugging, led to reduced HRV compared to real touches. Lower HRV is typically associated with stress (MacArthur & MacArthur, 2000; Vrijkotte et al., 2000) or cognitive engagement (Cinaz et al., 2010; Hjortskov et al., 2004; Mateo et al., 2012; Taelman et al., 2011). The passive nature of vicarious touch may explain this, as solely observing touch could increase cognitive engagement, leading to reduced HRV despite a calming HR response (Luque-Casado et al., 2013; Pendleton et al., 2016). Additionally, the short HRV recordings used in our study may not fully capture parasympathetic changes, as longer, 24-hour recordings are generally more reliable for this purpose (Bansal et al., 2009; Kim et al., 2018; Shaffer & Ginsberg, 2017). This may also explain why we did not find a significant increase in HRV during real stroking, such as the findings by Triscoli, Croy, Steudte-Schmiedgen, et al. (2017), where stroking occurred continuously and without interruption for an average duration of 35 minutes. Further research is needed to clarify the physiological mechanisms of vicarious touch, particularly in distinct HR and HRV patterns.

Theta

As hypothesised, all touch-types, whether with a close individual, a stranger, or vicarious, increased theta activity compared to rest. This supports existing research linking theta to attentional engagement with salient sensory stimuli (Iannetti et al., 2008; Michail et al., 2016) and positive affect (Ackerley, Carlsson, et al., 2014; Aftanas et al., 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Krause et al., 2000; Maulsby, 1971). However, contrary to expectations, no significant differences in theta increases were observed between experimental conditions for CT-optimal stroking. We had anticipated stronger theta responses for real stroking, especially from close individuals, given previous findings on the central role of affective touch in intimate relationships (Suvilehto et al., 2015), and that its regulatory function seems to be mediated by psychological intimacy (Debrot et al., 2013). These theta findings are consistent with HR responses, which also showed no substantial variation between experimental conditions for CT-optimal stroking, reinforcing the idea that the physiological effects of CT-optimal stroking may be largely independent of contextual factors in older adults, even if subjective affective ratings are not.

A distinction between real and vicarious touch was evident during hugs and handshakes, where real physical touch, produced stronger and more widespread theta activity. Hugs and handshakes engage deep pressure sensory pathways, which can be pleasant and activate similar brain regions to CT-optimal stroking (Case et al., 2021), but they differ in that CT-optimal stroking specifically targets CT-fibres (Wessberg & Norrsell, 1993). CT-fibres stimulation is consistently associated with positive affect, regardless of whether the stroking is delivered from a close individual (Triscoli, Croy, Olausson, et al., 2017), a stranger (Kirsch et al., 2018), robotically (Löken et al., 2009), via brush stroking (Löken et al., 2009), skin-to-skin contact (Kirsch et al., 2018), or observed vicariously (Haggarty et al., 2023). While the intrinsic positivity of CT-targeted touch in evoking positive affect remains a topic of debate (Sailer & Leknes, 2022), it is generally supported in contexts beyond close personal interactions, more so than for other touches. The underlying mechanisms for the affective and sensory processing of hugs and handshakes are less well understood. Vicarious hugs and handshakes, while still increasing theta, appear to engage less intense sensory and emotional processing, reflecting the attenuated neural impact of observing versus physically experiencing touch. Additionally, real touch was rated as more pleasant, suggesting a stronger emotional response, which may contribute to the heightened theta activity observed (Aftanas et al., 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Krause et al., 2000). Furthermore, perceived intention plays a crucial role in the affective value of touch (for a review see: Sailer & Leknes, 2022). The intention behind stroking is likely clearer across interaction modes, whereas the intention of vicarious hugs and handshakes may be more ambiguous compared to their real counterparts (McCann & McKenna, 1993), potentially moderating the emotional impact. In our study, participants were not provided with any context regarding the intention behind vicarious touches. Future research could explore the influence of perceived intention in vicarious touch by introducing context narratives.

Contrary to our expectations, no significant differences in theta activity were found between touches from close individuals and strangers. Previous research has consistently shown that touch between close individuals is associated with positive affect (Floyd, 1999; Löken et al., 2009; Pawling et al., 2017) and higher theta power (Ackerley, Carlsson, et al., 2014; Aftanas et al., 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Krause et al., 2000; Maulsby, 1971). However, our findings indicate that in older adults, the emotional closeness of the touch partner does not significantly modulate theta oscillations. This suggests that older adults may process touch as uniformly pleasant, regardless of the relationship context or subjective ratings, with theta response being driven more by the tactile stimulation itself rather than the emotional connection with the touch giver. These findings support research showing that the pleasantness of affective touch increases with age (Sehlstedt et al., 2016), indicating that touch in later adulthood is perceived more generally as positive. However, stranger hugs and handshakes elicited more widespread theta activity compared to their vicarious counterparts, a pattern that was less pronounced for touches from close individuals. The age-related “positivity effect” (Mather & Carstensen, 2005), characterised by reduced amygdala activation to negative but not positive stimuli (Gutchess et al., 2007; Leclerc & Kensinger, 2011; Mather et al., 2004), may help explain this finding. Given that the amygdala is involved in processing pleasant touch (Gordon et al., 2013; Spitoni et al., 2020; Voos et al., 2013), older adults may experience a broader or even enhanced perception of touch as positive, even from strangers. This suggests that the hedonic aspects of touch remain intact or are even heightened with age, independent of relational factors, providing a neurophysiological basis for the diminished selectivity of emotional closeness in tactile processing.

Finally, our findings show that hugs and handshakes elicited greater theta activity than stroking, with handshakes producing the most widespread increases, despite being rated as less pleasant. Theta power reflects emotional experiences and arousal (Güntekin & Başar, 2016; Knyazev, 2007), regardless of whether stimuli are positively or negatively valenced (Aftanas et al., 2001; Balconi & Lucchiari, 2006; Balconi & Pozzoli, 2009; Knyazev et al., 2009). In terms of pleasantness, hugging was rated as more pleasant than stroking, while handshakes were rated as less pleasant. Additionally, HR and HRV findings indicate calming effects for stroking and hugging, but not for handshakes. This may also indicate that hugs and handshakes were more salient than stroking (Iannetti et al., 2008; Michail et al., 2016). Thus, increased theta activity observed during hugs and handshakes may reflect heightened emotional experience, arousal, and salience, but with different valences: more positive than stroking for hugging and more negative than stroking for handshakes. Another possible explanation is that hugs and handshakes may stimulate Aβ-fibres more than stroking, given their greater pressure, larger contact areas, and involvement of glabrous skin, factors known to enhance theta responses (Kuc et al., 2023; Michail et al., 2016). Moreover, during vicarious touch, theta activity was higher for stroking and hugging compared to handshakes, suggesting that while vicarious handshakes may have been salient, this salience was likely not driven by affective factors.

It is also possible that some formal or tense emotions associated with handshakes (Åström, 1993; Nagy et al., 2020) may have been conflated with the positive emotions of handholding (Sened et al., 2023). While any touch enables two-way sensing, the tactile palms and fingers are much more sensitive than other body areas (Gibson & Craig, 2005; Morioka et al., 2008). Both handshakes and handholding engage both palms and fingers, allowing optimal tactile feedback between participants. This may facilitate bi-directional feedback important for homeostatic regulation, as suggested by evidence showing handholding promotes synchrony in skin conductance and brain activity (Goldstein et al., 2018; Reddan et al., 2020). To avoid contaminating results, participants were silent during handshakes, potentially making this touch more perceptually ambiguous and resulting in both outcomes of formal handshakes but also pleasant handholding. Further research is needed to clarify these effects.

In contrast to our findings, von Mohr et al (2018) reported theta suppression during affective touch, which they attributed to attentional and emotional regulatory processes observed in mindfulness and meditation (Chiesa et al., 2013; Mitchell et al., 2008; Tanaka et al., 2014; Uusberg et al., 2014; Yu et al., 2011). However, their paradigm involved participants remaining still with their eyes closed, potentially inducing a low-arousal or drowsy state, which can influence theta activity (Klimesch, 1999; Knyazev et al., 2006; Mitchell et al., 2008). In our study, participants had their eyes open and were moving during hugs and handshakes, which involved skin-to-skin contact rather than brush stroking, possibly accounting for the difference in theta dynamics. However, it should be noted that von Mohr et al (2018) expected increased theta in response to touch for the same reasons as the present study, reflecting attention to involuntary salient sensory stimuli (Iannetti et al., 2008; Michail et al., 2016) and processing of affectively valence cues (Aftanas & Golocheikine, 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Krause et al., 2000).

Beta and Alpha

Our findings demonstrated clear differences in beta and alpha activity between real and vicarious touch. Vicarious touch resulted in reduced beta and alpha activity compared to rest, with beta reductions observed during vicarious stroking and handshakes, while alpha reductions were observed across all vicarious touches. In contrast, increased beta and alpha activity was observed during real touches, with increased beta observed for all real touches, while increased alpha occurred during real hugs and handshakes. Prior studies reported beta and alpha reduction during tactile stimulation (Diego et al., 2004; Michail et al., 2016; Singh et al., 2014; von Mohr et al., 2018b), with beta oscillations thought to play a role in sensory integration (Brovelli et al., 2004; Simoes et al., 2003). However, it remains uncertain whether beta and alpha suppression is driven by tactile processing or primarily by anticipation (Foxe et al., 1998; Michail et al., 2016; von Mohr et al., 2018a). This ambiguity often arises when rest conditions directly precede touch stimulation, leading to increases in beta and alpha activity due to the anticipatory effects, especially for alpha (Foxe et al., 1998). Our study recorded the rest condition independently of other experimental conditions, which could explain why we did not find consistent beta and alpha reductions.

Instead, our observed beta and alpha reductions during vicarious touch, and only alpha reductions across all stroking interactions, likely reflect heightened attention and sensory engagement, given that both beta and alpha are inversely related to attention (Diego et al., 2004; Klimesch et al., 1998; Nunez, 2000; Shagass, 1972), and sensory processing (Bastiaansen et al., 2001; Brinkman et al., 2014). Additionally, reductions in alpha activity are associated with tactile observation (Coll et al., 2015; Perry et al., 2010). In our study, vicarious touches and stroking involved the most direct observation of the physical contact points. In contrast, real hugs obscured these contact points due to the close, intertwined nature of the interaction, while handshakes typically involve maintaining eye contact rather than focusing on the touch itself. This supports findings from Schirmer and McGlone (2019), who reported beta and alpha desynchronisation when participants focused on touch in social interaction images, indicating sensorimotor activation. Nonetheless, it should not be overlooked that posture differences may have influenced the unique effects observed in vicarious touch compared to real touches, and between stroking compared to hugs and handshakes. Participants were seated during vicarious touches and stroking interactions, but standing during real hugs and handshakes. Resting beta and alpha activity was significantly lower during sitting than standing. These posture differences were observed in frontal scalp sites for both beta and alpha, but were also present in parietal, temporal, and occipital sites for alpha activity. While significant differences were often more widespread during posture-mismatched conditions than present only at the scalp sites affected by rest condition differences, further research is needed to determine whether these beta and alpha reductions persist when posture is matched.

However, Schirmer and McGlone (2019) also found that touch images, compared to no-touch images, elicited higher alpha and beta power. This difference may be explained by complexity of touch stimuli. Studies showing alpha and beta suppression frequently used images focusing solely on the point of physical contact (Kim et al., 2022; Peled-Avron et al., 2016; Whitmarsh et al., 2011; Yang et al., 2009), while more complex, full-body images likely increase perceptual demands, similar to how motor imagery complexity elevates beta and alpha power (Brinkman et al., 2014). Our results suggest that the greater processing demands of real touch, and the inability to isolate observation of the touch, might explain the increased beta and alpha activity compared to vicarious touch. Notably, vicarious stroking and handshakes exhibited significantly less beta activity than rest, as did real stroking, likely due to the larger body areas and more dynamic movement involved in hugging, making these stimuli more challenging to process too.

Furthermore, increased beta power has previously been associated with more pleasant tactile experiences, particularly in right hemispheric temporo-parietal and frontal sites (Singh et al., 2014). The beta increases we observed during all real touch in temporal, occipital, and prefrontal sites support this, indicating that beta activity may reflect the hedonic valence of touch, which aligns with participants' ratings of higher pleasantness during real touches compared to vicarious touches. Previous electrophysiological studies have shown that temporo-parietal beta activity correlates with emotional states, demonstrating greater beta activity during emotionally positive tasks (Ray & Cole, 1985). Additionally, fMRI studies have identified the posterior insula, medial frontal cortex, and cingulate cortex as key brain regions involved in the hedonic experience of tactile stimulation (Björnsdotter et al., 2009; Gordon et al., 2013; Rolls et al., 2003; Voos et al., 2013). The topography of the beta activity we observed aligns with these neural sources. Additionally, inherently pleasurable tactile stimuli are known to activate inferior prefrontal regions, with afferent projections from the somatosensory cortex into the orbitofrontal cortex, inferior frontal gyrus, and adjacent anterior frontal operculum being associated with this sensation (Hagen et al., 2002). Our findings of beta increases at prefrontal electrode sites support this.

Regarding beta and alpha activity during interactions with close individuals versus strangers, we found higher beta activity at temporal and occipital scalp sites during stranger hugs and handshakes compared to those with close individuals. This finding could suggest that participants perceived stranger hugs and handshakes more positively, as increased temporo-parietal beta activity is associated with pleasant touch (Singh et al., 2014) and positive emotional states (Ray & Cole, 1985; Schutter et al., 2001). However, this interpretation contradicts subjective ratings of pleasantness and cardiovascular responses. Thus, this may be linked to the age-related “positivity effect” (Mather & Carstensen, 2005), where older adults tend to perceive or interpret experiences more positively, potentially leading to an enhanced response to touch from strangers. In contrast, no significant differences in alpha activity were observed between close and stranger hugs and handshakes, suggesting similar levels of attention and sensory processing regardless of emotional closeness (Bastiaansen et al., 2001; Brinkman et al., 2014; Diego et al., 2004; Klimesch et al., 1998; Nunez, 2000; Shagass, 1972). Consistent with the theta findings, there were also no differences in beta or alpha activity during close versus stranger stroking, further supporting the idea of universal perception of stroking as pleasant, at least among older adults.

In terms of beta and alpha differences between touch types, we observed significantly higher alpha activity during hugs than handshakes with close individuals. Given that increases in beta and alpha power are associated with greater processing demands (Brinkman et al., 2014), this elevated alpha activity during hugs may reflect the higher cognitive complexity involved in processing hugs compared to handshakes. This complexity is likely due to the larger body areas involved, the emotional significance of hugs, and the longer duration of contact in our experimental setup (hugs lasting 10 seconds versus 3 seconds for handshakes). However, no significant differences in beta power were found between hugs and handshakes with close individuals. Alpha oscillations are also associated with mindfulness, interoceptive awareness, and relaxation (Cahn & Polich, 2006; Lomas et al., 2015; Yu et al., 2011), suggesting that the higher alpha activity during hugs could indicate a more relaxed state, consistent with our HRV findings showing increased HRV during hugs with close individuals. Furthermore, the absence of significant differences in beta or alpha activity between stranger hugs and handshakes further supports the notion that hugs with close individuals may have a uniquely relaxing effect. For vicarious touch, beta activity was higher during stroking and hugs compared to handshakes. Lower beta activity during vicarious handshakes compared to other vicarious touches might indicate that handshakes were the least challenging to process, likely because they are not as emotionally driven. Moreover, we observed more alpha activity during vicarious handshakes than stroking, which could suggest lower tactile observation in this condition. Reductions in alpha activity are often linked to increased tactile observation (Coll et al., 2015; Perry et al., 2010), and the brief duration of contact during handshakes compared to stroking likely contributed to this effect. Finally, no significant differences were found in beta or alpha activity between vicarious stroking and hugs, indicating that these touch types might evoke similar levels of sensorimotor and attentional processing

Limitations and Future Directions

In summary, this study provides insights into the longitudinal touch patterns of older adults, their behavioural and physiological responses to stress based on cumulative touch frequency, and their electrophysiological responses to stroking, hugging, and handshakes, shared with close individuals, strangers, and vicariously.

Over a four-month period, older adults reported romantic partner touch, especially hugging, as the most frequent and pleasant, with hugs from family and friends also occurring frequently. However, they consistently expressed dissatisfaction with the amount of touch received from both partners and non-partners. Additionally, when comparing short-term and long-term retrospective reports of touch frequency, we found that short-term reports were more variable and indicated a higher touch frequency than long-term reports. Furthermore, increased touch frequency did not improve cognitive control or significantly affect physiological responses during a stressful task.

Our electrophysiological findings revealed distinct patterns for stroking compared to hugging and handshakes across close individual, stranger, and vicarious conditions. Stroking interactions yielded consistent responses, with no significant differences in pleasantness, HR and alpha activity reduction, or theta activity increases, suggesting that older adults' responses to stroking are less context-dependent than other touch types. In vicarious interactions, both stroking and hugging reduced both HR and HRV, reflecting a response characterised by calmness and arousal, though this interpretation is uncertain. In contrast, real hugs increased HRV, while handshakes with strangers raised HR, indicating distinct calming and arousing effects. Theta activity increased across all touch types and experimental conditions, suggesting that theta oscillations encode both real and vicarious sensory stimuli. Real hugs and handshakes elicited stronger responses compared to their vicarious counterparts, likely due to the activation of deep pressure sensory pathways and clearer intentions. Notably, theta oscillations did not correlate with the emotional closeness of the touch partner, implying that older adults may find real touches physiologically more pleasant regardless of their relational context. Beta and alpha activity patterns differentiated real from vicarious touch; vicarious interactions showed decreased beta and alpha activity, indicating heightened attention, whereas real touches resulted in increased activity, suggesting greater sensory integration and pleasantness. The heightened beta activity during stranger hugs and handshakes may reflect the age-related ‘positivity effect’. Lastly, greater alpha activity during hugs compared to handshakes may indicate the higher cognitive complexity associated with processing hugs, which require more emotional and physical engagement.

Overall, the present study provides evidence of how contextual factors, influence physiological responses to touch in an older adult population. However, these findings should be considered in light of several limitations, which also suggest directions for future research.

First, the inconsistent posture across conditions presents a methodological challenge. Although consistent posture would have been ideal, we prioritised minimising standing time for our older adult sample, and maintaining the naturalness of interactions. Participants stood during hugs and handshakes, but were seated for stroking and vicarious interactions, in line with existing research (Ackerley, Wasling, et al., 2014; Dueren et al., 2021; Feldhütter et al., 1990; Nagy et al., 2020; Smit et al., 2023). We found significant differences in resting HR, theta, beta, and alpha oscillations between seated and standing postures, but no differences in resting HRV. Additionally, not all scalp sites showed significant differences in theta, beta, and alpha oscillations. This suggests that our findings were not solely influenced by posture, as differences between conditions often exceeded those due to body posture. We matched rest posture to the majority of touch postures in each comparison. For instance, we used standing rest for hug comparisons, despite not matching vicarious hugs. Only all stroking and all vicarious comparisons had fully matched postures, as participants were seated across all conditions, thus seated rest was used too. By treating rest as an independent condition, we could directly compare touch interactions to rest and evaluate whether interactions significantly differed from one another or from rest. This approach also facilitated comparisons with previous studies, such as von Mohr et al (2018). Nevertheless, future studies should strive to match postures across all conditions to ensure validity. This would eliminate the confounding effects of posture and allow clearer attribution of physiological changes to touch interactions.

Second, the duration of touch interactions was not fully matched. Hugging was set to 10 seconds based on research suggesting this as the optimal duration (Dueren et al., 2021), and stroking was also set to 10 seconds to ensure consistency. Handshakes, however, were limited to three seconds to prevent increased stress responses (Feldhütter et al., 1990; Nagy et al., 2020). Each trial was repeated three times. These durations are consistent with previous studies, such as eight blocks of six-second brush strokes (von Mohr et al., 2018), and single trials of one-second hugs, five-second, and ten-second hugs (Dueren et al., 2021). These ultra-short recordings may not optimally capture HRV or parasympathetic changes. Although 24-hour recordings are most reliable for assessing HRV (Bansal et al., 2009; Kim et al., 2018; Shaffer & Ginsberg, 2017), this method is impractical for measuring HRV in response to hugs. We opted to use the standard deviation of NN intervals (SDNN) because it is a widely recognised measure of overall HRV (Wang & Huang, 2012). Other studies suggest that the root mean square of the successive differences in RR intervals (RMSSD) is better suited for ultra-short assessments (10 seconds to one minute), whereas SDNN typically required recordings longer than one minute (Nussinovitch et al., 2011). For example, Triscoli et al

(2017) employed continuous stroking for an average of 35 minutes, finding greater HRV activation than observed in our study. However, longer hugs (over 10 seconds) and handshakes (over three seconds) may be perceived as uncomfortable or stressful, consistent with findings that pleasantness and desire for touch decrease with repeated stimulation (Triscoli et al., 2014). Future studies should aim to maintain consistent interaction durations for better comparisons.

Third, this study delivered both real and vicarious touches without context and intention cues to focus solely on the physiological effects of touch itself. However, the role of context and intention cannot be overlooked, as they play a crucial role in the emotional impact of touch. For example, participants were reluctant to compare the pleasantness of fabrics without knowing their intended use, highlighting the importance of context (Ripin & Lazarsfeld, 1937). Additionally, findings from nursing literature suggest that touch is rated as more comforting when perceived as instrumental (e.g., to facilitate care) rather than affectionate, likely due to clearer and more interpersonally appropriate intentions associated with instrumental touch (McCann & McKenna, 1993). Future studies should examine the influence of intention behind interactions from individuals of varying emotional closeness, as well as vicarious touch, to determine how these factors affect touch perception and processing.

Fourth, our study focused on older adults, who tend to perceive touch as more emotionally meaningful and pleasant compared to younger adults (Guest et al., 2014; Sehlstedt et al., 2016), despite engaging in touch less frequently (Upenieks & Schafer, 2022). This demographic may benefit significantly from touch interventions. While much of the existing research on touch emphasises younger adults (Cruciani et al., 2021), it would be valuable to directly compare physiological responses to different types of touch, with close individuals, strangers, and vicariously in younger populations. Additionally, future research should aim to directly compare touch characteristics, as well as behavioural and physiological responses, between younger and older adults. Such studies would help determine whether cumulative touch influences acute stress responses and cognitive performance in other age groups, but also whether the electrophysiological patterns observed here, such as the context-independent response to stroking and differentiation between touch types more so than emotional closeness, also apply to younger adult or are unique to older populations.

Fifth, we did not examine sex differences due to insufficient statistical power. While existing research indicates that both men and women experience similar emotional and physiological benefits from touch with familiar individuals, such as romantic partners, evidenced by improvements in momentary affective states (Debrot et al., 2017; Debrot et al., 2013) and reductions in cortisol levels, HR, and blood pressure during stress (Ditzen et al., 2019; Ditzen et al., 2008), some differences also emerge. For instance, men may benefit more from touch interventions in terms of blood pressure, while women tend to find touch more pleasant (Holt-Lunstad et al., 2008; Russo et al., 2020). The dynamics shift further when considering touch between strangers; men may perceive caressing touch from female experimenters as rewarding, while women may not (Kirsch et al., 2018). However, it is unclear if these patterns extend to older adults. Therefore, it is unclear how sex influenced our findings, and if mane versus women perceived touch conditions different, thus, future studies should investigate how sex influences the neural correlates of touch.

Sixth, our experimental design may have combined the formal or tense emotional cues often associated with handshakes (Åström, 1993; Nagy et al., 2020) with the more positive emotions linked to handholding (Sened et al., 2023). To reduce potential confounds, participants remained silent during handshakes, possibly making this touch more perceptually ambiguous and contributing to mixed emotional effects. Given the high sensitivity of the palms and fingers (Gibson & Craig, 2005; Morioka et al., 2008), both handshakes and handholding provide rich tactile feedback, potentially enabling mutual regulation, as suggested by evidence that handholding can enhance synchrony in skin conductance and brain activity (Goldstein et al., 2018; Reddan et al., 2020). Future research should examine whether handshakes and handholding elicit similar effects when contextual cues are limited, and no verbal communication occurs during contact.

Seventh, we found no effect of past touch frequency on current stress resilience. Although prior research has linked frequent partner touch with positive physiological and psychological outcomes. This includes increased baseline oxytocin and reduced blood pressure (Light et al., 2005), lower perceived stress and higher positive mood (Burleson et al., 2007), quicker recovery from common colds (Cohen et al., 2015), reduced cortisol levels (Holt-Lunstad et al., 2008), improved cholesterol levels (Floyd et al., 2009), and elevated dopamine and serotonin (Field et al., 2004). It remains possible that individuals with more frequent touch and satisfying relationships derive greater benefit from acute touch during stressful tasks than those with less frequent touch or less fulfilling relationships. Understanding these dynamics may help clarify the role of touch history and relationship satisfaction in modulating responses to stress in older adults, informing potential therapeutic uses of touch in stress management.

Finally, this study’s participants lacked racial diversity, as all were white. This limits the generalisability of our findings, given that cultural differences can influence touch behaviour and perceptions (Remland et al., 1995; Schirmer et al., 2023). Future research should aim to replicate these results in more racially and culturally diverse populations to gain a broader understanding of touch dynamics. Additionally, all participants in the lab study had a close individual they felt comfortable touching, which might have biased the findings toward more positive outcomes. Exploring stranger and vicarious touch with individuals who do not have close touch partners could yield different results. Future studies should include participants without a touch partner to better understand touch responses across different relationship contexts. Moreover, participants knew in advance that the study involved touch interactions with both close individuals and strangers. This may have led to a self-selection bias, attracting individuals more comfortable with touch in general. Prior evidence suggests that people who are more comfortable with touch are more likely to engage in studies involving physical contact with strangers (Fromme et al., 1989). To address this bias, future studies should consider recruiting a more varied sample that includes individuals with different levels of touch comfort.

In conclusion, while tactile interactions are known to reduce stress and benefit physical health, older adults perceive touch as more emotionally meaningful and pleasant than younger adults but engage in it less frequently. This study sheds light on the complex interplay between touch characteristics and physiological responses in older adults. Over a four-month period, participants reported that while hugs from romantic partners, family, and friends were the most frequent and pleasant, they expressed dissatisfaction with the overall amount of touch received. Notably, our findings indicated that short-term and long-term reports of touch frequency differed, with short-term reports showing greater variability. Electrophysiological analyses revealed that stroking evoked consistent responses across contexts, indicating its universal pleasantness, while real hugs and handshakes elicited unique physiological effects that did not differ significantly between close individuals and strangers. This suggests that the type of touch is more influential than the emotional closeness of the touch giver. Furthermore, while both real and vicarious touches had distinct impacts on HR and HRV, the lack of correlation between theta activity and emotional closeness highlights the potential differences in neural and cardiovascular processing of real touch. Collectively, these findings may inform interventions to leverage touch for enhancing well-being in older populations, and call for further research to explore these dynamics across different age groups and contexts.

6. General Discussion

Overview

Research consistently underscores the protective role of touch in reducing stress (Dagnino-Subiabre, 2022; Fishman et al., 1995; Kidd et al., 2023) and its benefits for physical health (Field, 2010; Packheiser et al., 2023; Thomas & Kim, 2021). Older adults tend to find touch more emotionally meaningful and pleasant than younger adults (Guest et al., 2014; Sehlstedt et al., 2016), yet they engage in it less frequently (Upenieks & Schafer, 2022). Despite this, most studies focus on younger populations. This thesis sought to fill that gap by exploring the physiological health correlates of touch frequency and relationship context among older adults, using both cross-sectional and longitudinal data.

To expand on existing findings, this research employed secondary data from a large household panel survey, the National Social Life, Health and Aging Project (NSHAP), alongside experimental data collection of physiological and neural markers of touch. A further specific focus was placed on vicarious touch, known to activate similar brain regions as direct touch (Björnsdotter & Olausson, 2011; Haggarty et al., 2021; Meijer et al., 2022), and reduce perceived stress (Kirsch et al., 2024). Given the limited exploration of its emotional and physiological effects, particularly in everyday contexts like hugging, this thesis investigated how vicarious hugs, varying by perspective (first-person vs. third-person) and duration (10 vs. 30 seconds), affect physiological responses during stress and recovery. Additionally, this thesis addressed gaps in the literature that NSHAP could not, such as detailed characteristics of older adults' experiences, the accuracy of long-term retrospective touch reports, and direct comparisons of autonomic and neural responses to real versus vicarious touch in older adults. Specifically, the final component of this research directly compared how different types of touch are perceived, and how these types of touch are perceived when shared with individuals of different emotional closeness (e.g., partner, family, friends vs. strangers), while additionally comparing these real touches to their vicarious counterparts. Overall, providing an in-depth understanding of how various forms of touch, both real and vicarious, impact emotional and physiological health in older adults, and how the context and nature of interpersonal relationships influence these effects.

Findings from Chapter 2, examining the cross-sectional association between frequency of interpersonal touch and components of allostatic load, revealed that frequent touch with romantic partners was associated with better neuroendocrine health, while touch with other close individuals showed no significant associations. Chapter 3, which looked at the long-term association between touch frequency and components of allostatic load, found that frequent romantic partner touch was associated with better metabolic and cardiovascular health five years later. Similar to cross-sectional investigations in Chapter 2, there were no significant associations with other close adult touch frequency. Overall, this suggests that the short-term benefits off frequent partner touch are pronounced in neuroendocrine systems, while the long-term benefits are most apparent in metabolic and cardiovascular systems.

Chapter 4 investigated the physiological markers of vicarious hugs, varying in perspective (first-person vs. third-person) compared to a neutral hug (actor hugging a water bottle) and duration (10 seconds vs. 30 seconds), during video viewing, a stressful task, and post-stress recovery. Results showed no significant differences in heart rate (HR), heart rate variability (HRV), galvanic skin response (GSR), pupil dilation (PD), or expressions of joy between the different perspectives and durations of vicarious hugs compared to the neutral hug video. However, longer videos led to greater PD, indicating increased autonomic arousal regardless of perspective. Additionally, less joy was found during longer neutral hug videos compared to third-person hugs, suggesting that first-person perspectives of full-body touches may be more complex and less pleasant than third-person views. Although the Stroop task successfully induced stress, as shown by increased HR and GSR, neither first-person nor third-person hug videos buffered stress better than neutral videos. Interestingly, longer video exposure resulted in reduced PD during the Stroop task and post-stress recovery, indicating greater relaxation compared to shorter exposures. In summary, these findings suggest that while different perspectives and durations of vicarious hugs might not influence physiological responses to stress, longer exposures, regardless of context of hugs, might lead to greater autonomic arousal during exposure, while additionally leading to greater relaxation and reduced autonomic arousal during stressful tasks and during recovery.

Finally, Chapter 5 examined the touch behaviours of older adults over a four-month period, and explored how frequency of touch over four months was associated with cognitive and physiological stress responses (HR and HRV) during the Stroop task. Furthermore, Chapter 5 directly compared autonomic (HR and HRV) and neural oscillatory (EEG) patterns in response to different touch types (CT-optimal stroking, hugging, and handshakes), shared with individuals of varying emotional closeness (partner/friend/family, strangers, or vicarious). The longitudinal survey findings highlighted several key patterns. For example, older adults living with others, and those with greater relationship satisfaction, reported sharing more touch with partners. In terms of the characteristics of touch shared over four months, partner hugs emerged as the most frequent and pleasant, followed by hugs with friends and family. Additionally, older adults consistently reported wanted more touch than they experienced. Furthermore, increased touch frequency with partners or non-partners did not lead to improvements in cognitive control or cardiovascular stress responses during the Stroop task, suggesting that accumulated frequent touch may not enhance acute stress responses in older adults, unlike what has been shown for touch applied during stress.

Regarding autonomic and neural comparisons, findings revealed unique responses for CT-optimal stroking, whereby both real (close individual and stranger) and vicarious stroking reduced HR. Although vicarious touches generally, showed lower HRV, indicating arousal.

In contrast, real hugs, especially with close individuals, showed increased HRV, indicating greater parasympathetic activity and relaxation. Neural oscillatory patterns revealed increases in theta activity across all types of touch and all touch sources compared to rest, suggesting similar attentional engagement and positive affect (Ackerley, Carlsson, et al., 2014; Aftanas et al., 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Iannetti et al., 2008; Krause et al., 2000; Maulsby, 1971; Michail et al., 2016). Similar to HR findings, there were no significant differences in theta activity for CT-optimal stroking across touch source conditions, indicating that perceptions of CT-optimal stroking are independent of contextual factors in older adults, even if they are vicarious. However, differences in theta activity were observed between hugs and handshakes. Real hugs and handshakes produced stronger theta activation compared to their vicarious counterparts, however, when hugs and handshakes were real, no significant differences were observed between close individuals and strangers, suggesting that for older adults, the type of touch is a bigger driver for neural differences than whom it is shared with.

Similarly, differences in beta and alpha activity were observed between real and vicarious touch, with lower activity observed during vicarious touch, and increased activity during real touch, with CT-optimal touch showing alpha desynchronisation similar to vicarious touch, compared to rest. These differences are thought to represent attentional and sensory engagement differences in focusing on touch observation compared to more complex states while actually experiencing touch (Bastiaansen et al., 2001; Brinkman et al., 2014; Diego et al., 2004; Klimesch et al., 1998; Nunez, 2000; Shagass, 1972). However, increased beta activity, previously associated with pleasant tactile experiences (Singh et al., 2014), suggests a greater perception of pleasure during all real touches, consistent with participants' reports of higher pleasantness for real compared to vicarious touch. Additionally, higher temporal and occipital beta activity was observed during stranger hugs and handshakes compared to those with close individuals, suggesting an age-related “positivity effect” (Mather & Carstensen, 2005), where older adults tend to interpret experiences more favourably. Although this finding did not align with subjective pleasantness or cardiovascular responses, thus requiring future investigation. Alpha activity, associated with mindfulness and relaxation (Cahn & Polich, 2006; Lomas et al., 2015; Yu et al., 2011), was higher during real hugs, particularly with close individuals, supporting the HRV findings that suggested increased relaxation during close interactions. Thus, these findings suggest that theta oscillatory increases may be a marker of both tactile observation and sensation in older adults, while beta and alpha are responsible for differences in attentional processing, but also the hedonic properties of touch.

Demographic, Behaviour, and Desire Characteristics of Touch in Older Adults

The factors that may signal a risk of touch absence in older adults and the characteristics of their touch behaviours remain underexplored. Upenieks and Schafer (2022) investigated whether greeting touch, which are physical interactions such as embraces, kisses, and pats on the back occurring during social encounters (Jones & Yarbrough, 1985), varies according to older adults’ characteristics. They found that women were more likely than men to engage in greeting touch, aligning with social support literature suggesting that women maintain larger and more supportive social networks (Antonucci et al., 2004). Additionally, Upenieks and Schafer (2022) found no significant associations between ethnicity or socioeconomic status and touch in later life, despite evidence that low education and income are typically associated with lower social support (Fischer & Beresford, 2015). Furthermore, Upenieks and Schafer (2022) found that other interpersonal factors were associated with more frequent greeting touch, such as having a romantic partner, being employed, engaging in formal (e.g., volunteering for charitable organisations) and informal (e.g., getting together socially with friend or relatives) social activities.

Extending these findings, Chapter 2 of this thesis showed that women report more frequent touch with non-romantic individuals, suggesting that, in addition to greeting touches, women may engage in touch more often than men with non-romantic others. However, no sex difference was found for touch frequency with romantic partners, supporting findings that women tend to have larger, denser, and more supportive social networks and are more likely to exchange emotional support than men (Antonucci et al., 2004; Liebler & Sandefur, 2002; Taylor et al., 2016). In contrast to Upenieks and Schafer (2022), Chapter 2 also found that white and more educated older adults reported more frequent touch with both partners and non-partners. This difference may stem from Upenieks and Schafer's (2022) use of a greeting touch measure, while Chapter 2 focused on affectionate touch. These findings suggest that non-white older adults and those of lower socioeconomic status may face barriers to frequent romantic and non-romantic touch. Lower socioeconomic status is linked to less social support from partners and friends (Fischer & Beresford, 2015), potentially due to chronic stress and interpersonal strains associated with adverse socioeconomic conditions (Mickelson & Kubzansky, 2003), which contribute to social isolation in later life (Shankar et al., 2017). Ethnic differences may further influence these patterns, as white individuals often report more friendships at mid-life than other ethnicities (Griffin et al., 2006), and experience higher relationship quality (Bulanda & Brown, 2007). These differences in social relationships and relationship quality may explain the higher frequency of touch reported by white respondents in Chapter 2. Supporting this, Chapter 5 found that higher relationship quality was associated with more frequent partner touch, as found in existing findings from younger samples (Gulledge et al., 2003).

Additionally, Chapter 5 findings indicate that individuals who live with others report more frequent touch with romantic partners than those living alone, likely because cohabitation creates more opportunities for touch (McDaniel & Andersen, 1998). This finding aligns with similar findings from younger samples, showing that there is a substantial difference in the touch exposure between alone-living and married individuals (Trotter et al., 2018). Similarly, Chapter 2 shows that older adults engaging in more sexual touch with partners also engage in more affectionate touch, suggesting that both types of touch may form an integrated expression of relational closeness and comfort with physical intimacy. This aligns with research showing that affection mediates the association between sexual activity, life satisfaction, and positive emotions (Debrot et al., 2017). Interestingly, Chapter 2 also reveals that older adults who report frequent touch with romantic partners often engage in less touch with other close adults. This may be due to social norms or personal preferences that reserve touch for romantic relationships. In contrast, Chapter 5 finds that those with a strong affinity for social touch and comfort with intimacy tend to touch non-partners more frequently, suggesting that individuals comfortable with touch may express it across a wider range of relationships. This may differ from those who, whether by personal preference or social convention, largely limit touch to their romantic partners.

In the NSHAP, touch frequency from both romantic partners and other close individuals, is measured at two Waves of data collection. To our knowledge, NSHAP is the only nationally representative dataset that includes measures of older adult touch frequency, though these have limitations. First, the data does not specify the type of touch shared or the specific individuals involved in non-partner touch. Second, the wording of questions differs between Waves. In Wave 1, partner touch was assessed with, “In the last 12 months, how often have you engaged in the following activities: hugging, kissing, caressing, or other close physical contact with you partner?” Wave 2 revised this to, “In the last 12 months, how often have you engaged in the following activities? How often have you or your partner shared caring touch, such as a hug, sitting or lying cuddles up, a neck rub, or holding hands?” For non-partner touch, Wave 1 asked, “In the last 12 months, how often have you engaged in the following activities: hugging, holding, or other close physical contact with another adult?" In Wave 2, this became, "Other than your partner, how often have you and a person such as a friend, grandchild, or another adult, shared caring touch, such as a greeting hug, a touch on the arm, or a neck rub? (In the last 12 months, how often have you engaged in the following activities?)".

Thus, in Chapter 5, specific patterns of touch were observed in older adults. Findings showed that older adults rated partner touch as the most frequent and also the type of touch they desired most, aligning with findings from younger populations (Beßler et al., 2020) and suggesting that touch with romantic partners remains poignant with age. Among partner touches, hugging was the most frequent, with kissing and handholding occurring less often, and caressing being the least frequent. However, all types of partner touch were rated as similarly pleasant. Among non-romantic relationships, family hugs were the most frequent, followed by friend hugs, with family touches rated as more pleasant than friend touches. Touches with colleagues, neighbours, and acquaintances were the least frequent and rated less pleasant compared to those partners, family, and friends. Both the frequency and pleasantness of partner touches remained more stable over time than touches with non-partners. Participants expressed a general dissatisfaction with the quantity of touch they shared with partners and non-partners, particularly for romantic partners, and this feeling remained over time. Participants consistently desired more touch with romantic partners (hugging, kissing, caressing, and handholding) as well as with other adults (hugging and holding), paralleling findings in younger populations who report experiencing certain touches (e.g., hugging and stroking) less often than desired (Beßler et al., 2020).

Thus, certain demographic, relational, and individual factors appear to influence touch behaviours in older adults. Within romantic relationships, barriers to touch may be greater for individuals who are non-white, have lower education levels, experience lower relationship quality, live alone, or engage in less sexual touch. Outside of romantic relationships, men, non-white individuals, those with lower education, and those less comfortable with intimacy or social touch may similarly face reduced opportunities for touch. Notably, older adults express a greater desire for touch than they report receiving, particularly with romantic partners, whose touch remains the most frequent and sought-after into later years. Hugging emerges as the most commonly shared form of touch, especially with partners, family, and friends.

Emotional Closeness and Touch Type

The findings of this thesis highlight the influence of emotional closeness and touch type on physiological, affective, and neural responses to touch in older adults. Touch with romantic partners offers significant physiological benefits, including reduced blood pressure, lower cortisol, and increased stress resilience (Ditzen et al., 2007; Grewen et al., 2003). Moreover, research suggests that partner touch more effectively reduces stress and pain and enhances positive emotions than touch from friends, while simply being near a partner, rather than a friend, reduces threat-related activity in the amygdala over time (Coan et al., 2006; Floyd et al., 2018; Kreuder et al., 2017; Morriss et al., 2019). Thus, partner touch appears to be particularly effective in reducing stress and promoting positive emotions. Findings from Chapters 2 and 3 confirm that frequent partner touch is linked to multi-system health benefits in older adults, while touch from close but non-romantic individuals does not yield these effects. However, in Chapter 5, older adults expressed a desire for more touch not only from partners but also from other close individuals, implying that motivations for touch extend beyond physiological gain.

Touch from close individuals like family members or friends also offers substantial benefits, as these interactions provide emotional support and express a broader range of affect compared to stranger touch (Antonucci et al., 2014; Pisano et al., 1986). Partner touch shows greater reductions in neural threat responses, pain, and stress, and is perceived as more pleasant and emotionally resonant than stranger touch (Beßler et al., 2020; Coan et al., 2017; Coan et al., 2006; Floyd et al., 2018; Kreuder et al., 2017; Kreuder et al., 2019; Xu et al., 2023), though touch from strangers can also provide benefits, including lowering cortisol, blood pressure, respiratory rate, and pain (Dreisoerner et al., 2021; Papathanassoglou & Mpouzika, 2012). Chapter 5 findings show that older adults perceive hugs from close individuals (partners, friends, family) as more pleasant than those from strangers. Moreover, close individual hugs were associated with increased HRV, echoing findings linking emotionally significant hugs to increased HRV (Yoshida et al., 2020). Stroking, by contrast, appeared equally pleasant across all relational contexts, with similar HR reductions, suggesting that a calming effect independent of emotional closeness. This aligns with research indicating that CT-optimal stroking, whether by close individuals, strangers, or tactile devices, provides universally pleasant (Ackerley, Backlund Wasling, et al., 2014; Kirsch et al., 2018; Triscoli, Croy, Olausson, et al., 2017; Triscoli, Croy, Steudte-Schmiedgen, et al., 2017) and soothing (Björnsdotter & Olausson, 2011; Haggarty et al., 2021) effects.

Neural activity measurements further elucidates these effects. Chapter 5 shows that theta activity increased across all touch types, indicating similar attentional engagement and positive affect, regardless of emotional closeness (Ackerley, Carlsson, et al., 2014; Aftanas et al., 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Iannetti et al., 2008; Krause et al., 2000; Maulsby, 1971; Michail et al., 2016). However, hugs and handshakes from strangers elicited higher beta activity in temporal and occipital regions than from close individuals, potentially reflecting an age-related “positivity effect” (Mather & Carstensen, 2005). This beta increase, associated with pleasant touch and positive emotions

(Ray & Cole, 1985; Schutter et al., 2001; Singh et al., 2014), contrasts with subjective preferences for touch from close individuals, suggesting a neural receptiveness to all touch. Whereas, hugs from close individuals elicited higher alpha activity than handshakes, possibly reflecting a more relaxed state and greater cognitive processing due to the intimacy, larger contact area, and extended duration of hugs (Brinkman et al., 2014; Cahn & Polich, 2006; Lomas et al., 2015; Yu et al., 2011). Hugs and handshakes also elicited more theta activity than stroking, with handshakes showing the highest response despite lower pleasantness ratings. This may reflect heightened arousal or salience (Güntekin & Başar, 2016; Iannetti et al., 2008; Knyazev, 2007; Michail et al., 2016), increased Aβ-fibre activation (Kuc et al., 2023; Michail et al., 2016), or overlap with handholding. Additionally, no differences were found in beta or alpha activity between close and stranger stroking, supporting stroking's consistently pleasant perception in older adults.

These findings underscore that while CT-fibre activation likely drives the universal appeal of stroking, the impact of hugs and handshakes is modulated by emotional closeness. Overall, this thesis suggests that the physiological and affective responses to touch in older adults reflect a complex interplay between tactile sensation and relational context, where partner and close-individual touch provide layered benefits, yet all forms of touch are perceived as broadly positive in older age.

Touch Frequency and Stress in Older Adults

In Chapter 2, cross-sectional analyses of NSHAP data revealed that more frequent touch with romantic partners over the past 12 months was associated with better neuroendocrine health. Principal components analysis (PCA) of allostatic load biomarkers revealed that dehydroepiandrosterone (DHEA) and pulse rate were highly correlated, and we labelled this as neuroendocrine health. DHEA, a hormone produced by the adrenal glands, plays a central role in stress regulation. It has immune-boosting effects, including anti-inflammatory and anti-glucocorticoid properties (Suzuki et al., 1991), which are essential for regulating the hypothalamic-pituitary-adrenal (HPA) axis, which governs stress responses (Maninger et al., 2009). High levels of DHEA are associated with successful ageing, maintaining youthfulness, and disease prevention (Butler, 1997; Khorram, 1996). Meanwhile, pulse rate reflects vagal function, a component of the autonomic nervous system central to stress regulation (Porges, 2007). Together, DHEA and pulse serve as markers of primary mediators in the stress response, involving stress hormones, their antagonists, and inflammatory cytokines (McEwen, 2003). These mediators influence cellular functions such as enzyme activity, receptor sensitivity, ion channel behaviour, and gene expression, all of which are crucial for maintaining the body's physiological stability. Chronic imbalance in these primary mediators can lead to compensatory changes in secondary systems, including metabolic (e.g., insulin), cardiovascular (e.g., systolic and diastolic blood pressure), and immune functions (e.g., fibrinogen). These systems adjust their operating ranges to cope with stress, resulting in subclinical shifts. If stress persists, the body may reach a state of allostatic overload, where cumulative physiological strain leads to disease and other adverse health outcomes, known as tertiary outcomes (Juster et al., 2010). This pattern suggests that more frequent partner touch with romantic partners could help maintain neuroendocrine health in older adults. By enhancing DHEA levels and supporting vagal function, regular touch with partners may reduce the impact of primary stress mediators, thus limiting the need for compensatory changes in secondary systems.

Chapter 3 extended these findings by showing that frequent partner touch was associated with improved metabolic and cardiovascular health five years later, indicating potential long-term effects of touch on secondary allostatic systems in older adults. In contrast, touch frequency with other close adults showed no similar associations, nor did partner touch predict neuroendocrine health over the same period, suggesting the unique importance of partner touch for sustained health benefits. These findings align with research linking increased touch frequency to lower likelihood of chronic inflammation five years later in older adults (Thomas & Kim, 2021). Thus, these findings support the allostatic load theory, chronic imbalance in primary mediators (neuroendocrine health) can lead to compensatory changes in secondary systems, including metabolic (e.g., insulin), cardiovascular (e.g., systolic and diastolic blood pressure), and immune functions (e.g., fibrinogen). Therefore, frequent partner touch may contribute to neuroendocrine and autonomic regulation, reducing stress levels and preventing prolonged HPA axis and sympathetic activation. This may in turn lower baseline hormone levels, helping to maintain metabolic and cardiovascular health over time (Goldman et al., 2006; Karlamangla et al., 2002; Seeman et al., 2001). Allostatic load is a better predictor of mortality than metabolic syndrome components or individual mediators (Seeman et al., 2001) and can provide early warning signs for future adverse health outcomes (Beckie, 2012), suggesting that older adults who share touch infrequently with partners may be at a heightened risk or poor health and mortality.

The NSHAP findings in this research showed that frequent touch was associated with better stress-related health outcomes both cross-sectionally and longitudinally. However, Chapter 5 found that increased touch frequency over four months did not influenced HR and HRV responses during the Stroop task, which induces acute psychological stress. Prior studies have shown that touch delivered during (Drescher et al., 1985) or immediately before (Ditzen et al., 2007) a stressor can modulate cardiovascular responses, but Chapter 5 findings suggest that cumulative, everyday frequent touch may not provide similar buffering effects for acute stressors in older adults. Acute stress responses, such as HR and HRV changes in a short-term task, depend on immediate physiological reactions, primarily sympathetic nervous system activation. While frequent partner touch may support long-term stress regulation (as shown in Chapters 2 and 3), it appears less effective at modulating moment-to-moment autonomic responses to acute stress in older adults. Instead, regular partner touch may gradually lower baseline stress levels, contributing to reduced allostatic load rather than acute reactivity. Furthermore, given that autonomic flexibility tends to decrease with age (Lin & Heffner, 2023), older adults may experience less physiological benefit from touch-induced increases in vagal tone during acute stress. Therefore, older adults might derive more benefit from the chronic stress-reducing effects of regular touch rather than its immediate buffering capacity. Moreover, to our knowledge, the immediate effects of interpersonal touch on stress have yet to be examined in older adults. Future research should address this gap and compare these acute effects to the longer-term benefits of touch. It would also be valuable to investigate whether older adults who experience frequent touch gain greater acute benefits, as their systems may be better attuned to the regulatory effects of touch.

Vicarious Touch and Behavioural, Physiological, and Neural Responses

In exploring vicarious touch and its behavioural, physiological and neural effects, this thesis underscores both the potential and limitations of observed touch in promoting emotional and physiological responses similar to direct tactile experiences. Findings from Chapter 5 indicate that vicarious CT-optimal stroking (gentle stroking at 1-10 cm/s) was rated as less pleasant than real stroking, but vicarious stroking can reduce HR in older adults, akin to real stroking, highlighting its universal calming effects (Björnsdotter & Olausson, 2011; Haggarty et al., 2021). However, this similarity was exclusive to stroking; all forms of vicarious touches led to reduced HRV from rest, contrasting with real touch and indicating a unique arousal response likely tied to heightened cognitive engagement rather than relaxation (Cinaz et al., 2010; Hjortskov et al., 2004; Mateo et al., 2012; Taelman et al., 2011). Importantly, the arousal associated with vicarious stroking was coupled with a calming response reflected in reduced HR. This coexistence of activating and deactivating physiological responses may illustrate the emotional complexity of vicarious stroking, as complex emotional experiences often involve a blend of traditionally opposing emotional components (Berrios et al., 2015; Lindquist & Barrett, 2008). These findings are reminiscent of Autonomous Sensory Meridian Response (ASMR), which is characterised by a warm, tingling, and pleasant sensations triggered by sights and sounds, such as personal attention in hairdressing videos. ASMR is also linked to reduced HR and increased GSR, fostering feelings of social connectedness (Poerio et al., 2018). Given that both vicarious CT-optimal stroking and ASMR are suggested as potential tools for alleviating loneliness, a direct comparison of their effects would be beneficial.

In Chapter 5, vicarious hugs reduced HRV but did not produce the HR reductions seen with vicarious stroking, while Chapter 4 found no significant HRV change during vicarious hugs. This discrepancy may reflect age-related differences, as Chapter 5 involved older adults only, suggesting that HRV reductions during vicarious hugs may indicate a distinct arousal response in older adults. CT-optimal stroking and hugging likely engage different calming mechanisms. CT-optimal stroking, which involves gentle, rhythmic stroking at 1-10 cm/s on hair-bearing skin such as the forearm, activates CT-fibres and associated affective and reward pathways (Ackerley, Backlund Wasling, et al., 2014; Gordon et al., 2013; McGlone & Reilly, 2010). Hugging, by contrast, applies deep pressure, engages vagal afferents, and involves full-body contact, possibly activating alternative relaxation pathways (Case et al., 2021; Diego & Field, 2009; Kandel et al., 2000; McGlone & Reilly, 2010). Observing hugs may also require more cognitive processing due to greater visual complexity (e.g., limb position, clothing), potentially lessening its calming effect compared to observing stroking. Thus, while both touch types are perceived as pleasant (Case et al., 2021), vicarious hugs may not replicate the same calming effect as stroking when observed. This was regardless of perspective of the vicarious hug (first-person vs. third-person), duration (10 vs. 30 seconds) or whether the observed touch was with another person or a water bottle, as demonstrated in Chapter 4. Similarly, vicarious handshakes in Chapter 5 did not elicit reduced HR, possibly for similar reasons as vicarious hugs.

In terms of neural correlates, Chapter 5 revealed that all real and vicarious touches increased theta activity, a neural marker of attentional engagement and positive affect, suggesting a shared attentional response across touches. Notably, there were no significant differences in theta activity between real stroking and vicarious stroking, suggesting similar attentional engagement (Iannetti et al., 2008; Michail et al., 2016) and positive affect (Ackerley, Carlsson, et al., 2014; Aftanas et al., 2001; Aftanas et al., 2004; Aftanas et al., 2002; Balconi & Pozzoli, 2009; Krause et al., 2000; Maulsby, 1971). However, real hugs and handshakes produced stronger theta responses than their vicarious counterparts, indicating a deeper attentional and emotional engagement, likely due to the sensory depth of direct touch involving deep pressure pathways (Case et al., 2021). Moreover, longer exposure to vicarious hugs in Chapter 4 led to greater pupil dilation during viewing (indicating autonomic arousal) and reduced dilation during stress recovery, suggesting that longer exposures may lead to habituation, lowering arousal in subsequent stress tasks without the parasympathetic relaxation typical of real touch. Thus, while vicarious touch can engage attention and evoke mild autonomic arousal, its effects appear more observational and cognitive than emotionally supportive.

Beta and alpha patterns further distinguished real from vicarious touch: real touch increased beta and alpha activity, associated with positive emotional engagement, while vicarious touch generally reduced these rhythms. These difference likely reflects the greater processing demands of real touch, which involves richer sensory input and social context (Schirmer & McGlone, 2019). Studies focusing on just the touch itself show beta and alpha suppression (Kim et al., 2022; Peled-Avron et al., 2016; Whitmarsh et al., 2011; Yang et al., 2009), while more complex, full-body imagery elicits increased beta and alpha power, mirroring the demands of processing motor imagery (Brinkman et al., 2014). Notably, vicarious stroking and handshakes showed lower beta activity than at rest, a pattern observed for real stroking as well, possibly due to the complex visual and kinaesthetic elements in stimuli like hugs. Higher beta activity during real touches may also reflect hedonic experiences (Ray & Cole, 1985; Singh et al., 2014). These patterns suggest that while vicarious touch captures attention, real touch more effectively engages social-affective neural pathways, enhancing positive affect and sensory processing.

Contemporaneous Versus Long-term Retrospective Touch Reports

Chapters 2 and 3 used data from the NSHAP, including touch frequency measures through two self-report questions: (1) frequency of touch with romantic partners over the last 12 months, and (2) frequency of touch with other adults over the last 12 months. These questions were asked in two data collection waves, five years apart. Due to potential recall bias inherent in long-term retrospective self-reports, especially those concerning affective experiences (Lay et al., 2017; Mill et al., 2016; Parkinson et al., 1995), which could affect the accuracy of findings, we conducted an assessment in Chapter 5 to examine the reliability of these measures. To address this, participants were asked to respond to the same two NSHAP questions monthly over a four-month period. This allowed us to evaluate whether 12-month touch frequency reports were consistent over time. The findings showed general stability in participants' long-term reports (NSHAP questions) of touch frequency with both romantic partners and other adults. This consistency suggests that in the NSHAP, respondents' 12-month recall was likely stable and reliable. Had there been discrepancies between the monthly responses, it might have indicated potential shifts in memory accuracy due to recent experiences (Leigh, 1977), raising concerns about the reliability of a single 12-month question. These findings also suggest that individuals are unlikely to be influenced by recent or significant events when reconstructing their 12-month estimates. Thus, the consistency of responses supports the validity of the NSHAP's one-time 12-month touch frequency questions. However, it is important to acknowledge that social desirability bias could still be a factor in these reports (Van de Mortel, 2008).

Additionally, we compared long-term retrospective reports (12 months) of touch frequency to short-term retrospective reports (covering the last few days) to explore how they differ. Both long-term and short-term reports were generally stable over time, suggesting consistent recall. However, short-term reports showed greater variability, likely due to daily fluctuations influenced by situational factors like interpersonal conflict, which can temporarily reduce opportunities for touch (Bolger et al., 1989; Rook, 2001). This suggests that long-term and short-term touch frequency reports may capture different aspects of touch dynamics, potentially leading to distinct health associations. The stability of long-term reports indicates that they reflect more consistent and general patterns of touch behaviour, making them a reliable measure for assessing broader health outcomes in cross-sectional and longitudinal studies. Therefore, the findings in Chapters 2 and 3, which rely on these 12-month measures, are likely valid and meaningful. In contrast, the greater variability seen in short-term reports highlights their sensitivity to recent and situational influences. This means that short-term measures may better capture immediate fluctuations in touch behaviour, which might not be reflected in long-term reports. Consequently, while long-term reports are effective for identifying sustained patterns and their long-term health implications, short-term reports could offer valuable insights into how daily changes in touch frequency are linked to acute shifts in well-being.

Furthermore, short-term reports indicated more frequent touch with both partners and non-partners compared to long-term reports. This increased frequency and variability may result from the fine-grained response options available, allowing for more precise reporting than the broader averages captured in long-term assessments. Retrospective reports of partner and non-partner touch frequency over the past 12 months showed more stability than reports over the past few days. Partner touch frequency was particularly stable in long-term reports, while non-partner touch reports were less consistent. In contrast, short-term reports showed greater variability in partner touch frequency compared to non-partner touch frequency. These findings suggest that longitudinal surveys like the NSHAP may accurately capture stable patterns of partner touch but could underrepresent the frequency of touch and oversimplify touch dynamics. Thus, the non-significant associations found for touch with other close individuals may partly stem from this underreporting. Integrating short-term measures with more detailed response options could enhance our understanding of non-partner touch behaviours and their potential health effects. Therefore, future research should explore this area, as non-partner touch may represent a significant source of well-being that is not well captured in existing large datasets, such as the NSHAP. Additionally, the stability of long-term reports strengthens the evidence that frequent partner is linked to both short-term (neuroendocrine health) and long-term (metabolic and cardiovascular health) benefits, as observed in Chapters 2 and 3. Therefore, while the emphasis on long-term reports was appropriate for assessing sustained health outcomes, future research should investigate whether these associations persist when using more granular, short-term data.

Implications

The findings of this research carry significant implications for enhancing the health and well-being of older adults through touch. Notably, older adults express a desire for more touch than they currently receive, from both romantic partners and close individuals, corroborating findings from younger populations (Von Mohr et al., 2021b) and underscoring the necessity of interventions to promote touch in this population. Structured, touch-friendly activities can create safe environments that foster social contact, leveraging the age-related “positivity effect” to enhance community-based interactions (Mather & Carstensen, 2005) and in turn neuroendocrine health and long-term metabolic and cardiovascular health.

Our research further demonstrated the unique health benefits of regular romantic partner touch, revealing its association with improved neuroendocrine health and long-term cardiovascular and metabolic health. These findings extend research from younger populations, confirming that partner touch is strongly associated with physiological and psychological benefits (Coan et al., 2006; Ditzen et al., 2007; Grewen et al., 2003). They underscore the need for public health strategies that promote intimate partner touch as a preventative measure for managing stress and reducing long-term disease risk in ageing populations, including cardiovascular disease, a leading cause of mortality in the United States (Murphy et al., 2021; Rosamond et al., 2007). In fact, cardiovascular disease related deaths increased globally between 1990 and 2017 from 5.9 million to 9.3 million (Jagannathan et al., 2019). While frequent partner touch stabilised baseline stress levels, it does not significantly affect acute cardiovascular responses to a stressful task, indicating that its benefits are more pronounced in managing chronic stress rather than immediate reactivity. This finding suggests that interventions should prioritise cumulative touch experiences, which can be particularly beneficial for older adults as their autonomic flexibility declines with age (Lin & Heffner, 2023). However, it appears that the acute effects of touch warrant further investigation as well.

The type of touch also plays a critical role, with CT-optimal stroking and hugs showing cardiovascular relaxation effects during the touch experience. For hugs, increased HRV was observed only when it was shared with close individuals (partners, friends, family), similar to previously reporting findings that partner handholding increases HRV after stress (Conradi et al., 2020). However, for stroking, HR reductions were observed regardless of the emotional closeness of the provider. This insight has implications for therapeutic interventions in eldercare, suggesting a focus on the type of tactile experience is necessary when touch is delivered by a non-close individual, as well as training caregivers in techniques that maximise the sensory quality of touch. However, this suggests that familiarity with a touch giver may not be necessary to achieve some momentary relaxation effects from touch. Enhanced beta activity during real touches with strangers, especially in hugs and handshakes, supports an age-related positivity effect (Lin & Heffner, 2023), wherein older adults interpret experiences more favourably, which we suspect was the cause for favourable neural responses with strangers. This may imply that older adults are inclined to view diverse social interactions through a positive lens, which could be leveraged in social programs to encourage interpersonal interactions and diminish feelings of loneliness.

Demographic disparities in touch frequency, related to sex, ethnicity, education, cohabitation, and relationship quality, highlight the need for targeted public health initiatives that foster inclusive, touch-friendly environments. While some of these disparities have previously been shown in greeting touch behaviours in older adults (Upenieks & Schafer, 2022), this research extends these findings to interpersonal touch shared with close individuals that are not solely greeting touches. Programs designed to increase social interactions for at-risk groups could help mitigate the barriers to touch. For example, these disparities may be partly explained by smaller social networks and lower relationship quality, thus pointing to a need for intervention in these aspects of older age (Antonucci et al., 2004; Bulanda & Brown, 2007; Liebler & Sandefur, 2002; Taylor et al., 2016).

Vicarious touch elicited similar increases in theta activity as real touch, with no significant differences between real and vicarious stroking, suggesting comparable positive affect and engagement (Ackerley, Carlsson, et al., 2014; Michail et al., 2016). Vicarious CT-optimal stroking also reduced HR, a response previously observed only with real stroking (Triscoli, Croy, Olausson, et al., 2017). However, all forms of vicarious touch decreased

HRV, indicating arousal rather than relaxation (Luque-Casado et al., 2013; Pendleton et al., 2016). This response pattern for vicarious stroking in older adults, combining both activation and deactivation, parallels other complex emotional experiences, such as ASMR, which has shown potential for alleviating loneliness (Poerio et al., 2018). Comparing these effects directly could further elucidate the role of vicarious stroking in emotional support. Although longer exposure to vicarious hugs increased pupil dilation (indicating autonomic arousal), they lacked the stress-buffering effects of real hugs. Therefore, while vicarious stroking may offer supplementary comfort for individuals with limited access to physical contact, it does not fully replicate the benefits of direct touch.

Finally, this research highlights the value of using both short-term and long-term measures to capture touch frequency accurately. While, short-term retrospective reports may reflect immediate fluctuations due to situational factors, long-term reports provide stable patterns, suggesting unlikelihood of influence from recent events, indicating reliable measures in the NSHAP, the only nationally representative dataset measuring touch frequency and biomarkers in older adults. However, short-term reports may capture more frequent touch, suggesting that long-term measures may underestimate overall touch frequency, particularly with non-partners. Thus, integrating both types of measures could offer a more comprehensive understanding of how both short-term and long-term touch behaviours, allowing for better-designed interventions that address both long-term and acute well-being in older adults.

General Limitations and Future Directions

This research has several limitations that warrant consideration. First, the touches studied here in the laboratory were presented without contextual or intentional cues, limiting insight into how these factors might influence touch perception and its physiological effects. In Chapters 4 and 5, both real and vicarious touches were delivered without clarifying their purpose or the intention behind them. While this approach isolated the physiological effects of touch, the emotional impact of touch is known to vary significantly based on perceived context and intent. For example, prior studies indicate that contextual information, such as whether a touch is intended for care versus affection, enhances comfort and clarity in the recipient's interpretation (McCann & McKenna, 1993). Similarly, lack of information about the purpose of the touch can affect its perceived positivity and meaning (Morrison, 2023; Sailer & Leknes, 2022). Additionally, some forms of touch may be perceived as intrusive or even harmful, depending on the context and intent (Jones & Yarbrough, 1985; Ojanlatva, 1994), with potential for misuse or power assertion. Future research should explore how varying context and intent influence touch effects within relationships of varying closeness, to provide a more nuanced understanding of touch's psychological and physiological impacts across diverse social contexts.

Second, while Chapters 2, 3, and 5 focus on older adults, most existing touch research centres on younger populations, leaving a gap in direct age-based comparisons (Cruciani et al., 2021). Older adults find touch more emotionally meaningful than younger adults but engage in it less often (Guest et al., 2014; Sehlstedt et al., 2016; Upenieks & Schafer, 2022), which may influence their responses to touch interventions. Future research should directly compare behavioural and physiological responses to various types of touch, from close individuals, strangers, and vicarious sources, in both age groups. This would help determine if observed patterns, such as context-independent responses to stroking, are unique to older adults or apply more broadly. Furthermore, while Chapter 4 included a broad age range, it did not specifically focus on older adults' responses to vicarious touch. Future studies should explore how older adults uniquely respond to such touch and its impacts on emotional and stress responses. Furthermore, the Chapter 5 sample included only older adults comfortable with touch, potentially excluding those who are more touch-deprived or less comfortable with touch. For example, prior evidence suggests that people who are more comfortable with touch are more likely to engage in studies involving physical contact with strangers (Fromme et al., 1989). Future research should examine how touch is perceived among these individuals.

Third, although the NSHAP is a nationally representative dataset, it may reflect a WEIRD (Western, Educated, Industrialised, Rich, Democratic) sample (Pitesa & Gelfand, 2023), which limits the generalisability of findings to non-WEIRD populations. Future research should investigate touch across diverse cultural contexts, as cultural norms significantly influence touch frequency and meaning. Chapters 2 and 3 utilise NSHAP data from the United States, while Chapters 3 and 4 draw on data from the UK. Cultural differences in touch behaviour have been well-documented. For instance, Hall (1966) found that individuals from high-contact cultures tend to engage in closer physical proximity and touch more frequently than those from non-contact cultures. Research indicates that individuals in the UK, Northern Europe, North America, and Asia touch engage in less frequent touch compared to those in Latin or South America, or Southern Europe (Hall, 1966; Jourard, 1966). For example, Jourard (1966) observed couples in cafes in San Juan, Puerto Rico, and London, finding that Puerto Rican couples touched each other an average of 180 times per hour, while couples in London averaged zero touches per hour. Given these cultural variations, it is uncertain whether the findings from Chapters 2 and 3 would also apply in the UK context. Future studies should explore whether neuroendocrine, cardiovascular, and metabolic associations with increased partner touch frequency are consistent across different cultures.

Fourth, this research did not examine potential sex differences in response to touch. Prior research shows that both men and women experience emotional and physiological benefits from touch with familiar individuals, such as partners, which include improvements in mood and reductions in cortisol, heart rate, and blood pressure under stress (Debrot et al., 2017; Debrot et al., 2013; Ditzen et al., 2019; Ditzen et al., 2008). However, certain sex-based differences have been observed. For instance, men may experience greater reductions in blood pressure from touch interventions, while women tend to report greater pleasure from touch interactions (Holt-Lunstad et al., 2008; Russo et al., 2020). Responses to touch from strangers also vary by sex. Men often perceive caressing touch from female experimenters as rewarding, whereas women may not (Kirsch et al., 2018). Additionally, women generally respond more positively to non-sexual touch from strangers than men (Hertenstein et al., 2006), and Western men tend to avoid same-sex touch with acquaintances (Crawford, 1994). The context also plays a critical role for women, who respond more positively to touch in professional environments and more negatively when touched by opposite-sex strangers in informal contexts (Martin, 2012). Given these nuances and the limited focus on older adults in prior research, it is unclear how sex differences might have influenced our findings. Future studies should examine how sex influences the neural and emotional responses to touch across different ages and contexts. Additionally, exploring partner touch dynamics within older adult pairs could yield valuable insights. Specifically, researchers could investigate whether individuals' perceptions of touch align with those of their partners and how these perceptions relate to relationship quality and touch satisfaction. Moreover, examining synchrony in neural oscillations and HRV during partner touch in older adults could provide a deeper understanding of the physiological connections between partners over time.

Fifth, the measures used in Chapters 4 and 5 were not fully optimised. In Chapter 5, for instance, CT-optimal touch was compared to hugging and handshakes. The perceptual differences between these touch types stem from the body parts involved in giving and receiving touch. Non-reciprocal touch, like stroking, typically involve the receiver sitting still while the toucher uses their fingers to stroke their forearm. In contrast, active touching (such as hugging) engages motor processes and influences predictions about associated somatosensory experiences (Blakemore et al., 1998; Boehme et al., 2019). Active touch is more effortful and involves inhibitory processes that may dampen awareness of emerging somatosensory impressions (Boehme & Olausson, 2022). Consequently, comparing different touch types, some passive (like CT-optimal stroking) and some active (like hugging), can be challenging without accounting for these factors.

Finally, the study's physiological measures were not all optimally implemented. For example, HRV assessments are generally more reliable with longer measurement periods, often requiring recordings of up to 24 hours (Bansal et al., 2009; Kim et al., 2018; Shaffer & Ginsberg, 2017). For instance, Triscoli, Croy, Steudte-Schmiedgen, et al. (2017) noted significant HRV changes with continuous stroking lasting an average of 35 minutes. However, it is important to consider that the pleasantness and desire for touch can diminish over repeated exposures (Triscoli et al., 2014), and hugs are most pleasant between 5 and 10 seconds (Dueren et al., 2021), further complicating these comparisons. Lastly, resting baseline measures in Chapter 5 were matched to the majority of touch postures, though not all comparisons had a posture matched baseline. By treating rest as an independent condition, we could directly compare touch interactions to rest. Nevertheless, future studies should strive to match postures across all conditions to ensure validity, thereby eliminating the confounding effects of posture and allowing clearer attribution of physiological changes to touch interactions.

Final Summary and Contributions to the Field

This research provides new insights into the health-related benefits of touch frequency, type, and context among older adults, filling a critical gap in literature that predominantly addresses younger populations. By combining data from the National Social Life, Health, and Aging Project (NSHAP) with experimental measures of physiological, neural, and emotional responses, this study demonstrated the distinct, context-dependent impacts of touch in later life.

Our findings in older adults showed that frequent touch with romantic partners was associated with improved neuroendocrine health in cross-sectional analyses and better metabolic and cardiovascular health in longitudinal analyses on the NSHAP. This suggests that regular partner touch may mitigate the negative health outcomes associated with multi-system dysregulation in older adults. In contrast, touch with other close individuals showed no comparable associations. In examining vicarious hugs, we observed that while longer durations of vicarious hug observation increased autonomic arousal, indicated by pupil dilations, they did not serve a protective function during a stressful task or during post-stress recovery. Notably, the observer's perspective (first-person, third-person) did not make a difference in this response. Thus, vicarious hugs may not buffer stress or produce physiological relaxation to the extent that real touch can. These finding underscore the importance of both context and duration in eliciting beneficial effects of vicarious touch.

Furthermore, different types of touch, including CT-optimal stroking, hugging, and handshakes, shared with individuals of varying emotional closeness (close individual, stranger, and vicarious) were associated with varying physiological and neural responses. Real touch, particularly hugs, demonstrated enhanced hedonic and heart rate variability effects, indicating relaxation, especially when shared with close individuals. Although the findings also suggested that the type of touch may play a more significant role than emotional closeness in influencing neural responses among older adults. Specifically, CT-optimal stroking showed the most similarities across who it was received from and whether it was real or observed, including reduced heart rate and similar theta increases. Thus, these findings suggest that theta oscillatory increases may be a marker of both tactile observation and sensation in older adults, while beta and alpha are responsible for differences in attentional processing, but also the hedonic properties of touch in older adults. Additionally, we found that older adults expressed a strong desire for more touch than they currently receive which points to an unmet need and the potential impact of touch-focused interventions.

These insights could be used to support public health strategies aimed at promoting partner and interpersonal touch to improve both emotional and physiological well-being in older adults, particularly at-risk groups. With further scope for the use of vicarious stroking as a low-cost intervention for older adults in social care or clinical settings.

7. References

Abraira, V. E., & Ginty, D. D. (2013). The sensory neurons of touch. *Neuron, 79*(4), 618-639.

Ackerley, R., Backlund Wasling, H., Liljencrantz, J., Olausson, H., Johnson, R. D., & Wessberg, J. (2014). Human C-Tactile Afferents Are Tuned to the Temperature of a Skin-Stroking Caress. *The Journal of Neuroscience, 34*(8), 2879-2883. https://doi.org/10.1523/jneurosci.2847-13.2014

Ackerley, R., Carlsson, I., Wester, H., Olausson, H., & Backlund Wasling, H. (2014). Touch perceptions across skin sites: differences between sensitivity, direction discrimination and pleasantness. *Frontiers in behavioral neuroscience, 8,* 54.

Ackerley, R., Eriksson, E., & Wessberg, J. (2013). Ultra-late EEG potential evoked by preferential activation of unmyelinated tactile afferents in human hairy skin. *Neuroscience letters, 535*, 62-66.

Ackerley, R., Hassan, E., Curran, A., Wessberg, J., Olausson, H., & McGlone, F. (2012). An fMRI study on cortical responses during active self-touch and passive touch from others. *Frontiers in behavioral neuroscience, 6,* 51.

Ackerley, R., Saar, K., McGlone, F., & Backlund Wasling, H. (2014). Quantifying the sensory and emotional perception of touch: differences between glabrous and hairy skin. *Frontiers in behavioral neuroscience, 8,* 34.

Ackerley, R., Wasling, H. B., Liljencrantz, J., Olausson, H., Johnson, R. D., & Wessberg, J. (2014). Human C-tactile afferents are tuned to the temperature of a skin-stroking caress. *Journal of Neuroscience, 34*(8), 2879-2883.

Adler, J., & Gillmeister, H. (2019). Bodily self-relatedness in vicarious touch is reflected at early cortical processing stages. *Psychophysiology*, *56*(12), e13465.

Adler, J., Schabinger, N., Michal, M., Beutel, M. E., & Gillmeister, H. (2016). Is that me in the mirror? Depersonalisation modulates tactile mirroring mechanisms. *Neuropsychologia, 85*, 148-158.

Aftanas, L., Varlamov, A., Pavlov, S., Makhnev, V., & Reva, N. (2001). Affective picture processing: event-related synchronization within individually defined human theta band is modulated by valence dimension. *Neuroscience letters, 303*(2), 115-118.

Aftanas, L. I., & Golocheikine, S. A. (2001). Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: high-resolution EEG investigation of meditation. *Neuroscience letters, 310*(1), 57-60.

Aftanas, L. I., Reva, N. V., Varlamov, A. A., Pavlov, S. V., & Makhnev, V. P. (2004). Analysis of evoked EEG synchronization and desynchronization in conditions of emotional activation in humans: temporal and topographic characteristics. *Neuroscience and behavioral physiology, 34*, 859-867.

Aftanas, L. I., Varlamov, A. A., Pavlov, S. V., Makhnev, V. P., & Reva, N. V. (2002). Time-dependent cortical asymmetries induced by emotional arousal: EEG analysis of event-related synchronization and desynchronization in individually defined frequency bands. *International journal of Psychophysiology, 44*(1), 67-82.

Ainsworth, M. D. S., Blehar, M. C., Waters, E., & Wall, S. N. (2015). *Patterns of attachment: A psychological study of the strange situation*. Psychology press.

Akselrod, S., Gordon, D., Ubel, F. A., Shannon, D. C., Berger, A. C., & Cohen, R. J. (1981). Power spectrum analysis of heart rate fluctuation: a quantitative probe of beat-to-beat cardiovascular control. *Science, 213*(4504), 220-222.

Anderson, E., & McCormack, M. (2015). Cuddling and spooning: Heteromasculinity and homosocial tactility among student-athletes. *Men and masculinities, 18*(2), 214-230.

Anderson, J. G., & Taylor, A. G. (2011). Effects of healing touch in clinical practice: a systematic review of randomized clinical trials. *Journal of Holistic Nursing*, *29*(3), 221-228.

Andreassi, J. L. (2010). *Psychophysiology: Human behavior and physiological response*. Psychology press.

Anisfeld, E., Casper, V., Nozyce, M., & Cunningham, N. (1990). Does infant carrying promote attachment? An experimental study of the effects of increased physical contact on the development of attachment. *Child Development, 61*(5), 1617-1627.

Antonucci, T., Akiyama, H., & Takahashi, K. (2004). Attachment and close relationships across the life span. *Attachment & human development, 6*(4), 353-370.

Antonucci, T. C., Ajrouch, K. J., & Birditt, K. S. (2014). The convoy model: Explaining social relations from a multidisciplinary perspective. *The Gerontologist, 54*(1), 82-92.

Aracena, C., Basterrech, S., Snáel, V., & Velásquez, J. (2015). Neural networks for emotion recognition based on eye tracking data. 2015 IEEE International Conference on Systems, Man, and Cybernetics,

Armel, K. C., & Ramachandran, V. S. (2003). Projecting sensations to external objects: evidence from skin conductance response. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *270*(1523), 1499-1506.

Armitage, R., & Nellums, L. B. (2020). COVID-19 and the consequences of isolating the elderly. *The Lancet Public Health, 5*(5), e256.

Arnsten, A. F. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nature reviews neuroscience, 10*(6), 410-422.

Åström, J. (1993). *Introductory greeting behaviour in relation to sex, age, physical characteristics, attitudes, personality, and psychopathology: Approaches by interviews, observations, and experiments* Linköpings universitet].

Åström, J. (1994). Introductory greeting behaviour: A laboratory investigation of approaching and closing salutation phases. *Perceptual and Motor Skills, 79*(2), 863-897.

Augustine, J. R. (1996). Circuitry and functional aspects of the insular lobe in primates including humans. *Brain research reviews, 22*(3), 229-244.

Ausubel, J. (2020). Older people are more likely to live alone in the US than elsewhere in the world.

Azevedo, R. T., Macaluso, E., Avenanti, A., Santangelo, V., Cazzato, V., & Aglioti, S. M. (2013). Their pain is not our pain: brain and autonomic correlates of empathic resonance with the pain of same and different race individuals. *Human brain mapping, 34*(12), 3168-3181.

Bai, S., Repetti, R. L., & Sperling, J. B. (2016). Children’s expressions of positive emotion are sustained by smiling, touching, and playing with parents and siblings: A naturalistic observational study of family life. *Developmental psychology, 52*(1), 88.

Balconi, M., & Lucchiari, C. (2006). EEG correlates (event-related desynchronization) of emotional face elaboration: a temporal analysis. *Neuroscience letters, 392*(1-2), 118-123.

Balconi, M., & Pozzoli, U. (2009). Arousal effect on emotional face comprehension: frequency band changes in different time intervals. *Physiology & behavior, 97*(3-4), 455-462.

Bali, A., & Jaggi, A. S. (2015). Clinical experimental stress studies: methods and assessment. *Reviews in the Neurosciences, 26*(5), 555-579.

Bansal, D., Khan, M., & Salhan, A. (2009). A review of measurement and analysis of heart rate variability. 2009 International Conference on Computer and Automation Engineering,

Bastiaansen, M. C., Böcker, K. B., Brunia, C. H., De Munck, J. C., & Spekreijse, H. (2001). Event-related desynchronization during anticipatory attention for an upcoming stimulus: a comparative EEG/MEG study. *Clinical Neurophysiology, 112*(2), 393-403.

Baumeister, R. F., & Leary, M. R. (2017). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Interpersonal development*, 57-89.

Beatty, J. (1982). Task-evoked pupillary responses, processing load, and the structure of processing resources. *Psychological bulletin, 91*(2), 276.

Beckie, T. M. (2012). A systematic review of allostatic load, health, and health disparities. *Biological Research for Nursing, 14*(4), 311-346.

Beebe-Center, J. G. (1935). Pleasantness and unpleasantness.

Bekkali, S., Youssef, G. J., Donaldson, P. H., Albein-Urios, N., Hyde, C., & Enticott, P. G. (2021). Is the putative mirror neuron system associated with empathy? A systematic review and meta-analysis. *Neuropsychology review, 31*, 14-57.

Bell, R. A., Daly, J. A., & Gonzalez, M. C. (1987). Affinity-maintenance in marriage and its relationship to women's marital satisfaction. *Journal of Marriage and the Family*, 445-454.

Bellard, A., Trotter, P., McGlone, F., & Cazzato, V. (2022). Vicarious ratings of self vs. other-directed social touch in women with and recovered from Anorexia Nervosa. *Scientific reports, 12*(1), 13429.

Bellard, A., Trotter, P. D., McGlone, F. L., & Cazzato, V. (2023). Role of medial prefrontal cortex and primary somatosensory cortex in self and other-directed vicarious social touch: a TMS study. *Social cognitive and affective neuroscience, 18*(1). https://doi.org/10.1093/scan/nsad060

Beltrán, M. I., Dijkerman, H. C., & Keizer, A. (2020). Affective touch experiences across the lifespan: Development of the Tactile Biography questionnaire and the mediating role of attachment style. *PLoS One, 15*(10), e0241041.

Bennett, R. H., Bolling, D. Z., Anderson, L. C., Pelphrey, K. A., & Kaiser, M. D. (2014). fNIRS detects temporal lobe response to affective touch. *Social cognitive and affective neuroscience, 9*(4), 470-476.

Berkman, L. F., Kawachi, I., & Glymour, M. M. (2014). *Social epidemiology*. Oxford University Press.

Berkman, L. F., & Syme, S. L. (1979). Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents. *American journal of Epidemiology, 109*(2), 186-204.

Berrios, R., Totterdell, P., & Kellett, S. (2015). Eliciting mixed emotions: a meta-analysis comparing models, types, and measures. *Frontiers in psychology, 6*, 428.

Bertheaux, C., Toscano, R., Fortunier, R., Roux, J.-C., Charier, D., & Borg, C. (2020). Emotion measurements through the touch of materials surfaces. *Frontiers in human neuroscience, 13*, 455.

Beßler, R., Bendas, J., Sailer, U., & Croy, I. (2020). The "Longing for Interpersonal Touch Picture Questionnaire": Development of a new measurement for touch perception. *International Journal of Psychology, 55*(3), 446-455.

Bigger, J., Fleiss, J. L., Rolnitzky, L. M., & Steinman, R. C. (1993). The ability of several short-term measures of RR variability to predict mortality after myocardial infarction. *Circulation, 88*(3), 927-934.

Björnsdotter, M., Löken, L., Olausson, H., Vallbo, Å., & Wessberg, J. (2009). Somatotopic organization of gentle touch processing in the posterior insular cortex. *Journal of Neuroscience, 29*(29), 9314-9320.

Björnsdotter, M., Morrison, I., & Olausson, H. (2010). Feeling good: on the role of C fiber mediated touch in interoception. *Experimental brain research, 207*(3), 149-155.

Björnsdotter, M., & Olausson, H. (2011). Vicarious responses to social touch in posterior insular cortex are tuned to pleasant caressing speeds. *Journal of Neuroscience, 31*(26), 9554-9562.

Blakemore, S.-J., Bristow, D., Bird, G., Frith, C., & Ward, J. (2005). Somatosensory activations during the observation of touch and a case of vision–touch synaesthesia. *Brain, 128*(7), 1571-1583.

Blakemore, S.-J., Wolpert, D. M., & Frith, C. D. (1998). Central cancellation of self-produced tickle sensation. *Nature neuroscience, 1*(7), 635-640.

Boehme, R., Hauser, S., Gerling, G. J., Heilig, M., & Olausson, H. (2019). Distinction of self-produced touch and social touch at cortical and spinal cord levels. *Proceedings of the National Academy of Sciences, 116*(6), 2290-2299.

Boehme, R., & Olausson, H. (2022). Differentiating self-touch from social touch. *Current Opinion in Behavioral Sciences, 43*, 27-33.

Bolger, N., DeLongis, A., Kessler, R. C., & Schilling, E. A. (1989, Nov). Effects of daily stress on negative mood. *J Pers Soc Psychol, 57*(5), 808-818. https://doi.org/10.1037//0022-3514.57.5.808

Boucsein, W. (2012). *Electrodermal activity*. Springer Science & Business Media.

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology, 45*(4), 602-607.

Braithwaite, J. J., Watson, D. G., Jones, R., & Rowe, M. (2013). A guide for analysing electrodermal activity (EDA) & skin conductance responses (SCRs) for psychological experiments. *Psychophysiology, 49*(1), 1017-1034.

Brauer, J., Xiao, Y., Poulain, T., Friederici, A. D., & Schirmer, A. (2016). Frequency of maternal touch predicts resting activity and connectivity of the developing social brain. *Cerebral cortex, 26*(8), 3544-3552.

Brennan, K. A., Wu, S., & Loev, J. (1998). Adult romantic attachment and individual differences in attitudes toward physical contact in the context of adult romantic relationships.

Brinkman, L., Stolk, A., Dijkerman, H. C., de Lange, F. P., & Toni, I. (2014). Distinct roles for alpha-and beta-band oscillations during mental simulation of goal-directed actions. *Journal of Neuroscience, 34*(44), 14783-14792.

Brothers, L. (1990). The neural basis of primate social communication. *Motivation and emotion, 14*, 81-91.

Brovelli, A., Ding, M., Ledberg, A., Chen, Y., Nakamura, R., & Bressler, S. L. (2004). Beta oscillations in a large-scale sensorimotor cortical network: directional influences revealed by Granger causality. *Proceedings of the National Academy of Sciences, 101*(26), 9849-9854.

Brown, T., Giddens, R., & Wilson, S. (2021). Longitudinal Associations of Physical Touch with Loneliness among Older Adults. *Innovation in Aging, 5*(Supplement_1), 1038-1038. https://doi.org/10.1093/geroni/igab046.3711

Bufalari, I., Aprile, T., Avenanti, A., Di Russo, F., & Aglioti, S. M. (2007). Empathy for pain and touch in the human somatosensory cortex. *Cerebral cortex, 17*(11), 2553-2561.

Bufalari, I., & Ionta, S. (2013). The social and personality neuroscience of empathy for pain and touch. *Frontiers in human neuroscience, 7*, 393.

Bulanda, J. R., & Brown, S. L. (2007). Race-ethnic differences in marital quality and divorce. *Social Science Research, 36*(3), 945-967.

Burgdorf, J., & Panksepp, J. (2001). Tickling induces reward in adolescent rats. *Physiology & behavior, 72*(1-2), 167-173.

Burgoon, J. K. (1991). Relational message interpretations of touch, conversational distance, and posture. *Journal of Nonverbal Behavior*, *15*, 233-259.

Burgoon, J. K., Buller, D. B., & Woodall, W. G. (1996). Nonverbal communication: The unspoken dialogue. *(No Title)*.

Burgoon, J. K., Walther, J. B., & Baesler, E. J. (1992). Interpretations, evaluations, and consequences of interpersonal touch. *Human communication research*, *19*(2), 237-263.

Burleson, M. H., Roberts, N. A., Munson, A. A., Duncan, C. J., Randall, A. K., Ha, T., Sioni, S., & Mickelson, K. D. (2022). Feeling the absence of touch: Distancing, distress, regulation, and relationships in the context of COVID-19. *Journal of Social and Personal Relationships*, *39*(1), 56-79.

Burleson, M. H., Trevathan, W. R., & Todd, M. (2007). In the mood for love or vice versa? Exploring the relations among sexual activity, physical affection, affect, and stress in the daily lives of mid-aged women. *Archives of sexual behavior, 36,* 357-368.

Buschmann, M. T., Hollinger-Smith, L. M., & Peterson-Kokkas, S. E. (1999). Implementation of expressive physical touch in depressed older adults. *Journal of Clinical Geropsychology, 5*, 291-300.

Butler, R. (1997). Super hype for super hormones. *Geriatrics, 52*(2), 13-14.

Cabibihan, J.-J., & Chauhan, S. S. (2015). Physiological responses to affective tele-touch during induced emotional stimuli. *IEEE Transactions on Affective Computing, 8*(1), 108-118.

Cacioppo, J. T., Cacioppo, S., & Boomsma, D. I. (2014). Evolutionary mechanisms for loneliness. *Cognition & emotion, 28*(1), 3-21.

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological bulletin, 132*(2), 180.

Campagnoli, R. R., Krutman, L., Vargas, C. D., Lobo, I., Oliveira, J. M., Oliveira, L., Pereira, M. G., David, I. A., & Volchan, E. (2015). Preparing to caress: a neural signature of social bonding. *Frontiers in psychology, 6*, 16.

Candia-Rivera, D., Boehme, R., & Salamone, P. C. (2024). Autonomic modulations to cardiac dynamics in response to affective touch: Differences between social touch and self-touch. *bioRxiv*, 2024.2002. 2020.581146.

Cardini, F., Costantini, M., Galati, G., Romani, G. L., Làdavas, E., & Serino, A. (2011). Viewing one's own face being touched modulates tactile perception: an fMRI study. *Journal of Cognitive Neuroscience, 23*(3), 503-513.

Carmichael, M. S., Humbert, R., Dixen, J., Palmisano, G., Greenleaf, W., & Davidson, J. M. (1987). Plasma oxytocin increases in the human sexual response. *The Journal of Clinical Endocrinology & Metabolism, 64*(1), 27-31.

Carter, C. S. (1998). Neuroendocrine perspectives on social attachment and love. *Psychoneuroendocrinology, 23*(8), 779-818.

Cascio, C. J., Moore, D., & McGlone, F. (2019). Social touch and human development. *Developmental cognitive neuroscience, 35*, 5-11.

Case, L. K., Laubacher, C. M., Olausson, H., Wang, B., Spagnolo, P. A., & Bushnell, M. C. (2016). Encoding of touch intensity but not pleasantness in human primary somatosensory cortex. *Journal of Neuroscience, 36*(21), 5850-5860.

Case, L. K., Liljencrantz, J., McCall, M. V., Bradson, M., Necaise, A., Tubbs, J., Olausson, H., Wang, B., & Bushnell, M. C. (2021). Pleasant deep pressure: expanding the social touch hypothesis. *Neuroscience, 464*, 3-11.

Casler, L. (1965). The effects of extra tactile stimulation on a group of institutionalized infants. *Genetic Psychology Monographs*.

Cekaite, A., & Goodwin, M. H. (2021). Touch and social interaction. *Annual Review of Anthropology, 50*(1), 203-218.

Chandola, T., Kumari, M., Booker, C. L., & Benzeval, M. (2022). The mental health impact of COVID-19 and lockdown-related stressors among adults in the UK. *Psychological medicine, 52*(14), 2997-3006.

Chang, Y.-C., Lin, W.-M., & Hsieh, S.-T. (2004). Effects of aging on human skin innervation. *Neuroreport, 15*(1), 149-153.

Chaplin, W. F., Phillips, J. B., Brown, J. D., Clanton, N. R., & Stein, J. L. (2000). Handshaking, gender, personality, and first impressions. *Journal of Personality and Social Psychology, 79*(1), 110.

Chiesa, A., Serretti, A., & Jakobsen, J. C. (2013). Mindfulness: Top–down or bottom–up emotion regulation strategy? *Clinical psychology review, 33*(1), 82-96.

Chiesa, P. A., Liuzza, M. T., Acciarino, A., & Aglioti, S. M. (2015). Subliminal perception of others’ physical pain and pleasure. *Experimental brain research, 233*, 2373-2382.

Cinaz, B., La Marca, R., Arnrich, B., & Tröster, G. (2010). Monitoring of mental workload levels.

Coan, J. A. (2008). Toward a neuroscience of attachment. *Handbook of attachment: Theory, research, and clinical applications, 2*, 241-265.

Coan, J. A. (2010). Adult attachment and the brain. *Journal of Social and Personal Relationships, 27*(2), 210-217.

Coan, J. A., Beckes, L., Gonzalez, M. Z., Maresh, E. L., Brown, C. L., & Hasselmo, K. (2017). Relationship status and perceived support in the social regulation of neural responses to threat. *Social cognitive and affective neuroscience, 12*(10), 1574-1583.

Coan, J. A., Schaefer, H. S., & Davidson, R. J. (2006). Lending a hand: Social regulation of the neural response to threat. *Psychological science*, *17*(12), 1032-1039.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. routledge.

Cohen, S. (2004). Social relationships and health. *American psychologist, 59*(8), 676.

Cohen, S., Janicki-Deverts, D., Turner, R. B., & Doyle, W. J. (2015). Does hugging provide stress-buffering social support? A study of susceptibility to upper respiratory infection and illness. *Psychological science, 26*(2), 135-147.

Coll, M.-P., Bird, G., Catmur, C., & Press, C. (2015). Cross-modal repetition effects in the mu rhythm indicate tactile mirroring during action observation. *Cortex, 63*, 121-131.

Collins, N. L. (1996). Revised adult attachment scale. *Behavior therapy*.

Collins, N. L., & Read, S. J. (1990). Adult attachment, working models, and relationship quality in dating couples. *Journal of Personality and Social Psychology, 58*(4), 644.

Conradi, H., Noordhof, A., & Arntz, A. (2020). Improvement of conflict handling: Hand-holding during and after conflict discussions affects heart rate, mood, and observed communication behavior in romantic partners. *Journal of Sex & Marital Therapy, 46*(5), 419-434.

Corey, S. M., Vizzard, M. A., Badger, G. J., & Langevin, H. M. (2011). Sensory innervation of the nonspecialized connective tissues in the low back of the rat. *Cells Tissues Organs, 194*(6), 521-530.

Costello, A. B., & Osborne, J. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical assessment, research, and evaluation, 10*(1), 7.

Craft, N., & Schwartz, J. B. (1995). Effects of age on intrinsic heart rate, heart rate variability, and AV conduction in healthy humans. *American Journal of Physiology-Heart and Circulatory Physiology, 268*(4), H1441-H1452.

Craig, A. D. (2008). Interoception and emotion: a neuroanatomical perspective. *Handbook of emotions, 3*(602), 272-288.

Craig, A. D. (2009). How do you feel—now? The anterior insula and human awareness. *Nature reviews neuroscience, 10*(1), 59-70.

Crawford, C. (1994). Effects of sex and sex roles on avoidance of same-and opposite-sex touch. *Perceptual and Motor Skills, 79*(1), 107-112.

Critchley, H. D. (2002). Electrodermal responses: what happens in the brain. *The Neuroscientist, 8*(2), 132-142.

Croy, I., Luong, A., Triscoli, C., Hofmann, E., Olausson, H., & Sailer, U. (2016). Interpersonal stroking touch is targeted to C tactile afferent activation. *Behavioural Brain Research SreeTestContent1, 297,* 37-40.

Cruciani, G., Zanini, L., Russo, V., Mirabella, M., Palamoutsi, E. M., & Spitoni, G. F. (2021). Strengths and weaknesses of affective touch studies over the lifetime: A systematic review. *Neuroscience & Biobehavioral Reviews, 127,* 1-24.

D’Alonzo, K. T., Munet-Vilaro, F., Carmody, D. P., Guarnaccia, P. J., Linn, A. M., & Garsman, L. (2019). Acculturation stress and allostatic load among Mexican immigrant women. *Revista latino-americana de enfermagem, 27.*

Dagnino-Subiabre, A. (2022). Resilience to stress and social touch. *Current Opinion in Behavioral Sciences, 43,* 75-79.

Davidovic, M., Jönsson, E. H., Olausson, H., & Björnsdotter, M. (2016). Posterior superior temporal sulcus responses predict perceived pleasantness of skin stroking. *Frontiers in human neuroscience, 10*, 432.

De Kloet, E. R., Joëls, M., & Holsboer, F. (2005). Stress and the brain: from adaptation to disease. *Nature reviews neuroscience, 6*(6), 463-475.

Debrot, A., Meuwly, N., Muise, A., Impett, E. A., & Schoebi, D. (2017). More than just sex: Affection mediates the association between sexual activity and well-being. *Personality and Social Psychology Bulletin, 43*(3), 287-299.

Debrot, A., Schoebi, D., Perrez, M., & Horn, A. B. (2013). Touch as an interpersonal emotion regulation process in couples’ daily lives: The mediating role of psychological intimacy. *Personality and Social Psychology Bulletin, 39*(10), 1373-1385.

Debrot, A., Schoebi, D., Perrez, M., & Horn, A. B. (2014). Stroking your beloved one's white bear: Responsive touch by the romantic partner buffers the negative effect of thought suppression on daily mood. *Journal of Social and Clinical Psychology, 33*(1), 75-97.

Debrot, A., Stellar, J. E., Dan-Glauser, E., & Klumb, P. L. (2024). Touch as a stress buffer? Gender differences in subjective and physiological responses to partner and stranger touch. *Journal of Nonverbal Behavior*, 1-20.

Debrot, A., Stellar, J. E., MacDonald, G., Keltner, D., & Impett, E. A. (2021). Is touch in romantic relationships universally beneficial for psychological well-being? The role of attachment avoidance. *Personality and Social Psychology Bulletin, 47*(10), 1495-1509.

Della Longa, L., Dragovic, D., & Farroni, T. (2021). In touch with the heartbeat: newborns' cardiac sensitivity to affective and non-affective touch. *International journal of environmental research and public health, 18*(5), 2212.

Della Longa, L., Gliga, T., & Farroni, T. (2019). Tune to touch: Affective touch enhances learning of face identity in 4-month-old infants. *Developmental cognitive neuroscience, 35*, 42-46.

Devine, S. L., Walker, S. C., Makdani, A., Stockton, E. R., McFarquhar, M. J., McGlone, F. P., & Trotter, P. D. (2020). Childhood adversity and affective touch perception: a comparison of United Kingdom care leavers and non-care leavers. *Frontiers in psychology, 11,* 557171.

Di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: a neurophysiological study. *Experimental brain research, 91,* 176-180.

Diego, M. A., & Field, T. (2009). Moderate pressure massage elicits a parasympathetic nervous system response. *International Journal of neuroscience, 119*(5), 630-638.

Diego, M. A., Field, T., Sanders, C., & Hernandez-Reif, M. (2004). Massage therapy of moderate and light pressure and vibrator effects on EEG and heart rate. *International Journal of neuroscience, 114*(1), 31-44.

Ditzen, B., Germann, J., Meuwly, N., Bradbury, T. N., Bodenmann, G., & Heinrichs, M. (2019). Intimacy as related to cortisol reactivity and recovery in couples undergoing psychosocial stress. *Psychosomatic Medicine, 81*(1), 16-25.

Ditzen, B., & Heinrichs, M. (2014). Psychobiology of social support: the social dimension of stress buffering. *Restorative neurology and neuroscience, 32*(1), 149-162.

Ditzen, B., Hoppmann, C., & Klumb, P. (2008). Positive couple interactions and daily cortisol: On the stress-protecting role of intimacy. *Psychosomatic Medicine, 70*(8), 883-889.

Ditzen, B., Neumann, I. D., Bodenmann, G., von Dawans, B., Turner, R. A., Ehlert, U., & Heinrichs, M. (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. *Psychoneuroendocrinology, 32*(5), 565-574.

Dolinski, D. (2010). Touch, compliance, and homophobia. *Journal of Nonverbal Behavior, 34*, 179-192.

Donovan, N. J., Wu, Q., Rentz, D. M., Sperling, R. A., Marshall, G. A., & Glymour, M. M. (2017). Loneliness, depression and cognitive function in older US adults. *International journal of geriatric psychiatry, 32*(5), 564-573.

Dreisoerner, A., Junker, N. M., Schlotz, W., Heimrich, J., Bloemeke, S., Ditzen, B., & van Dick, R. (2021). Self-soothing touch and being hugged reduce cortisol responses to stress: A randomized controlled trial on stress, physical touch, and social identity. *Comprehensive Psychoneuroendocrinology, 8*, 100091.

Drescher, V. M., Gantt, H. W., & Whitehead, W. E. (1980). Heart rate response to touch1. *Psychosomatic Medicine, 42*(6), 559-565.

Drescher, V. M., Whitehead, W. E., Morrill-Corbin, E. D., & Cataldo, M. F. (1985). Physiological and subjective reactions to being touched. *Psychophysiology, 22*(1), 96-100.

Dueren, A. L., Vafeiadou, A., Edgar, C., & Banissy, M. J. (2021). The influence of duration, arm crossing style, gender, and emotional closeness on hugging behaviour. *Acta psychologica, 221*, 103441.

Ebisch, S. J., Ferri, F., Salone, A., Perrucci, M. G., D'Amico, L., Ferro, F. M., Romani, G. L., & Gallese, V. (2011). Differential involvement of somatosensory and interoceptive cortices during the observation of affective touch. *Journal of Cognitive Neuroscience, 23*(7), 1808-1822.

Ebisch, S. J., Perrucci, M. G., Ferretti, A., Del Gratta, C., Romani, G. L., & Gallese, V. (2008). The sense of touch: embodied simulation in a visuotactile mirroring mechanism for observed animate or inanimate touch. *Journal of Cognitive Neuroscience, 20*(9), 1611-1623.

Eckstein, M., Mamaev, I., Ditzen, B., & Sailer, U. (2020). Calming Effects of Touch in Human, Animal, and Robotic Interaction—Scientific State-of-the-Art and Technical Advances [Review]. *Frontiers in Psychiatry, 11*, Article 555058. https://doi.org/10.3389/fpsyt.2020.555058

Edwards, D. J., Young, H., Curtis, A., & Johnston, R. (2018). The immediate effect of therapeutic touch and deep touch pressure on range of motion, interoceptive accuracy and heart rate variability: a randomized controlled trial with moderation analysis. *Frontiers in integrative neuroscience, 12*, 41.

Ekman, P., & Friesen, W. V. (1976). Measuring facial movement. *Environmental psychology and nonverbal behavior, 1*, 56-75.

Ellingsen, D.-M., Wessberg, J., Chelnokova, O., Olausson, H., Laeng, B., & Leknes, S. (2014). In touch with your emotions: oxytocin and touch change social impressions while others' facial expressions can alter touch. *Psychoneuroendocrinology, 39*, 11-20.

Evans, S., Mikocka-Walus, A., Klas, A., Olive, L., Sciberras, E., Karantzas, G., & Westrupp, E. M. (2020). From "it has stopped our lives" to "spending more time together has strengthened bonds": The varied experiences of Australian families during COVID-19. *Frontiers in psychology, 11*, 588667.

Fairhurst, M. T., Löken, L., & Grossmann, T. (2014). Physiological and behavioral responses reveal 9-month-old infants' sensitivity to pleasant touch. *Psychological science, 25*(5), 1124-1131.

Families, O. (2021). households in the UK: 2020. *London, UK: Office for National Statistics, 357*, 358.

Fancourt, D., Steptoe, A., & Bu, F. (2021). Trajectories of anxiety and depressive symptoms during enforced isolation due to COVID-19 in England: a longitudinal observational study. *The Lancet Psychiatry, 8*(2), 141-149.

Fast, C. D., & McGann, J. P. (2017). Amygdalar gating of early sensory processing through interactions with locus coeruleus. *Journal of Neuroscience, 37*(11), 3085-3101.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods, 39*(2), 175-191.

Feeney, B. C. (2004). A secure base: responsive support of goal strivings and exploration in adult intimate relationships. *Journal of Personality and Social Psychology, 87*(5), 631.

Feldhütter, I., Schleidt, M., & Eibl-Eibesfeldt, I. (1990). Moving in the beat of seconds: analysis of the time structure of human action. *Ethology and Sociobiology, 11*(6), 511-520.

Feldman, R., & Eidelman, A. I. (2003). Skin-to-skin contact (Kangaroo Care) accelerates autonomic and neurobehavioural maturation in preterm infants. *Developmental Medicine & Child Neurology, 45*(4), 274-281.

Feldman, R., Singer, M., & Zagoory, O. (2010). Touch attenuates infants' physiological reactivity to stress. *Developmental science, 13*(2), 271-278.

Feldman, R., Weller, A., Sirota, L., & Eidelman, A. I. (2002). Skin-to-Skin contact (Kangaroo care) promotes self-regulation in premature infants: sleep-wake cyclicity, arousal modulation, and sustained exploration. *Developmental psychology, 38*(2), 194.

Ferrell-Torry, A. T., & Glick, O. J. (1993). The use of therapeutic massage as a nursing intervention to modify anxiety and the perception of cancer pain [Article]. *Cancer nursing, 16*(2), 93-101. https://doi.org/10.1097/00002820-199304000-00002

Field, T. (2010). Touch for socioemotional and physical well-being: A review. *Developmental review, 30*(4), 367-383.

Field, T., Diego, M., Hernandez-Reif, M., Schanberg, S., & Kuhn, C. (2004). Massage therapy effects on depressed pregnant women. *Journal of Psychosomatic Obstetrics & Gynecology, 25*(2), 115-122.

Field, T., Ironson, G., Scafidi, F., Nawrocki, T., Goncalves, A., Burman, I., Pickens, J., Fox, N., Schanberg, S., & Kuhn, C. (1996). Massage therapy reduces anxiety and enhances EEG pattern of alertness and math computations. *International Journal of neuroscience, 86*(3-4), 197-205.

Field, T., Poling, S., Mines, S., Bendell, D., & Veazey, C. (2020). Touch deprivation and exercise during the COVID-19 lockdown april 2020. *Medical Research Archives, 8*(8).

Field, T. M. (1998). Massage Therapy Effects [Article]. *American psychologist, 53*(12), 1270-1281. https://doi.org/10.1037/0003-066X.53.12.1270

Field, T. M. (1998). Massage therapy effects. *American psychologist, 53*(12), 1270.

Fink, J., Goetsch, L., Lindstrand, N., Morris, S., & Skoczylas, A. (2014). Flexibility Using the Stroop Test While Monitoring Heart Rate, Respiration Rate, and Electrodermal Activity Levels.

Fischer, C. S., & Beresford, L. (2015). Changes in support networks in late middle age: The extension of gender and educational differences. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 70*(1), 123-131.

Fisher, J. D., Rytting, M., & Heslin, R. (1976). Hands touching hands: Affective and evaluative effects of an interpersonal touch. *Sociometry*, 416-421.

Fishman, E., Turkheimer, E., & DeGood, D. E. (1995). Touch relieves stress and pain. *Journal of Behavioral Medicine, 18*, 69-79.

Fletcher, G. J., Simpson, J. A., & Thomas, G. (2000). The measurement of perceived relationship quality components: A confirmatory factor analytic approach. *Personality and Social Psychology Bulletin, 26*(3), 340-354.

Floyd, K. (1999). All touches are not created equal: Effects of form and duration on observers' interpretations of an embrace. *Journal of Nonverbal Behavior, 23*, 283-299.

Floyd, K. (2014). Relational and health correlates of affection deprivation. *Western Journal of Communication, 78*(4), 383-403.

Floyd, K., Boren, J. P., Hannawa, A. F., Hesse, C., McEwan, B., & Veksler, A. E. (2009). Kissing in marital and cohabiting relationships: Effects on blood lipids, stress, and relationship satisfaction. *Western Journal of Communication, 73*(2), 113-133.

Floyd, K., Hesse, C., & Haynes, M. T. (2007). Human affection exchange: XV. Metabolic and cardiovascular correlates of trait expressed affection. *Communication Quarterly, 55*(1), 79-94.

Floyd, K., Ray, C. D., Raalte, L. v., Stein, J. B., & Generous, M. A. (2018). Interpersonal Touch Buffers Pain Sensitivity in Romantic Relationships but Heightens Sensitivity between Strangers and Friends. *Research in Psychology and Behavioral Sciences*.

Floyd, K., & Voloudakis, M. (1999a). Affectionate behavior in adult platonic friendships interpreting and evaluating expectancy violations. *Human communication research, 25*(3), 341-369.

Floyd, K., & Voloudakis, M. (1999b). Attributions for expectancy violating changes in affectionate behavior in platonic friendships. *The Journal of psychology, 133*(1), 32-48.

Folkman, S., & Lazarus, R. S. (1985). If it changes it must be a process: study of emotion and coping during three stages of a college examination. *Journal of Personality and Social Psychology, 48*(1), 150.

Folkman, S., & Moskowitz, J. T. (2000). Positive affect and the other side of coping. *American psychologist, 55*(6), 647.

Forster, B., & Abad-Hernando, S. (2024). In your skin? Somatosensory cortex is purposely recruited to situate but not simulate vicarious touch. *Neuroimage, 289*, 120561.

Frank, D. A., Klass, P. E., Earls, F., & Eisenberg, L. (1996). Infants and young children in orphanages: One view from pediatrics and child psychiatry. *Pediatrics, 97*(4), 569-578.

Friesen, W. V., & Ekman, P. (1983). EMFACS-7: Emotional Facial Action Coding System.

Fromme, D. K., Jaynes, W. E., Taylor, D. K., Hanold, E. G., Daniell, J., Rountree, J. R., & Fromme, M. L. (1989). Nonverbal behavior and attitudes toward touch. *Journal of Nonverbal Behavior, 13*, 3-14.

Fusaro, M., Tieri, G., & Aglioti, S. M. (2016). Seeing pain and pleasure on self and others: behavioral and psychophysiological reactivity in immersive virtual reality. *Journal of neurophysiology, 116*(6), 2656-2662.

Galinsky, A. M., McClintock, M. K., & Waite, L. J. (2014). Sexuality and physical contact in national social life, health, and aging project wave 2. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 69*(Suppl_2), S83-S98.

Gallace, A., & Spence, C. (2010). The science of interpersonal touch: an overview. *Neuroscience & Biobehavioral Reviews, 34*(2), 246-259.

Gallese, V., & Ebisch, S. (2013). Embodied simulation and touch: The sense of touch in social cognition. *Phenomenology and Mind*(4), 196-210.

Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in cognitive sciences, 2*(12), 493-501.

Ganea, D. A., Bexter, A., Günther, M., Gardères, P.-M., Kampa, B. M., & Haiss, F. (2020). Pupillary dilations of mice performing a vibrotactile discrimination task reflect task engagement and response confidence. *Frontiers in behavioral neuroscience, 14,* 159.

Gazzola, V., Spezio, M. L., Etzel, J. A., Castelli, F., Adolphs, R., & Keysers, C. (2012). Primary somatosensory cortex discriminates affective significance in social touch. *Proceedings of the National Academy of Sciences, 109*(25), E1657-E1666.

Gibson, G. O., & Craig, J. C. (2005). Tactile spatial sensitivity and anisotropy. *Perception & Psychophysics, 67*(6), 1061-1079.

Gillmeister, H., Bowling, N., Rigato, S., & Banissy, M. J. (2017). Inter-individual differences in vicarious tactile perception: a view across the lifespan in typical and atypical populations. *Multisensory Research, 30*(6), 485-508.

Goldman, N., Turra, C. M., Glei, D. A., Seplaki, C. L., Lin, Y.-H., & Weinstein, M. (2006). Predicting mortality from clinical and nonclinical biomarkers. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 61*(10), 1070-1074.

Goldstein, P., Weissman-Fogel, I., Dumas, G., & Shamay-Tsoory, S. G. (2018). Brain-to-brain coupling during handholding is associated with pain reduction. *Proceedings of the National Academy of Sciences, 115*(11), E2528-E2537.

Gøransson, L., Mellgren, S., Lindal, S., & Omdal, R. (2004). The effect of age and gender on epidermal nerve fiber density. *Neurology, 62*(5), 774-777.

Gordon, I., Voos, A. C., Bennett, R. H., Bolling, D. Z., Pelphrey, K. A., & Kaiser, M. D. (2013). Brain mechanisms for processing affective touch. *Human brain mapping, 34*(4), 914-922.

Gottlieb, G. (1971). Ontogenesis of sensory function in birds and mammals. *The biopsychology of development, 81*.

Graff, T. C., Luke, S. G., & Birmingham, W. C. (2019). Supportive hand-holding attenuates pupillary responses to stress in adult couples. *PLoS One, 14*(2), e0212703.

Granholm, E. E., & Steinhauer, S. R. (2004). Pupillometric measures of cognitive and emotional processes. *International journal of Psychophysiology*.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and clinical neurophysiology, 55*(4), 468-484.

Graven-Nielsen, T., Mense, S., & Arendt-Nielsen, L. (2004). Painful and non-painful pressure sensations from human skeletal muscle. *Experimental brain research, 159,* 273-283.

Green, L. (2017). The trouble with touch? New insights and observations on touch for social work and social care. *British Journal of Social Work, 47*(3), 773-792.

Green, L., & Moran, L. (2021). Covid-19, social distancing and the ‘scientisation’of touch: Exploring the changing social and emotional contexts of touch and their implications for social work. *Qualitative Social Work, 20*(1-2), 171-178.

Grewen, K. M., Anderson, B. J., Girdler, S. S., & Light, K. C. (2003). Warm partner contact is related to lower cardiovascular reactivity. *Behavioral medicine, 29*(3), 123-130.

Grewen, K. M., Girdler, S. S., & Light, K. C. (2005). Relationship quality: effects on ambulatory blood pressure and negative affect in a biracial sample of men and women. *Blood pressure monitoring, 10*(3), 117-124.

Griffin, M. L., Amodeo, M., Clay, C., Fassler, I., & Ellis, M. A. (2006). Racial differences in social support: Kin versus friends. *American Journal of Orthopsychiatry, 76*(3), 374-380.

Grillot, M., Fauvel, J., Cottet-Emard, J., Laville, M., Peyrin, L., Pozet, N., & Zech, P. (1995). Spectral analysis of stress-induced change in blood pressure and heart rate in normotensive subjects. *Journal of cardiovascular pharmacology, 25*(3), 448-452.

Grunwald, M., Weiss, T., Mueller, S., & Rall, L. (2014). EEG changes caused by spontaneous facial self-touch may represent emotion regulating processes and working memory maintenance. *Brain research, 1557,* 111-126.

Guéguen, N. (2004). Nonverbal encouragement of participation in a course: The effect of touching. *Social Psychology of Education, 7*(1), 89-98.

Guéguen, N., & Fischer-Lokou, J. (2002). An evaluation of touch on a large request: A field setting. *Psychological Reports, 90*(1), 267-269.

Guéguen, N., & Fischer-Lokou, J. (2003). Another evaluation of touch and helping behavior. *Psychological Reports, 92*(1), 62-64.

Guerrero, L. K. (1997). Nonverbal involvement across interactions with same-sex friends, opposite-sex friends and romantic partners: Consistency or change? *Journal of Social and Personal Relationships, 14*(1), 31-58.

Guest, S., Mehrabyan, A., Ackerley, R., McGlone, F., Phillips, N., & Essick, G. (2014). Tactile experience does not ameliorate age-related reductions in sensory function. *Experimental aging research*, *40*(1), 81-106.

Gulledge, A. K., Gulledge, M. H., & Stahmannn, R. F. (2003). Romantic physical affection types and relationship satisfaction. *The American Journal of Family Therapy, 31*(4), 233-242.

Güntekin, B., & Başar, E. (2016). Review of evoked and event-related delta responses in the human brain. *International journal of Psychophysiology, 103,* 43-52.

Gutchess, A. H., Kensinger, E. A., Yoon, C., & Schacter, D. L. (2007). Ageing and the self-reference effect in memory. *Memory, 15*(8), 822-837.

Haans, A., & IJsselsteijn, W. A. (2009). I'm always Touched by Your Presence, Dear": Combining Mediated Social Touch with Morphologically Correct Visual Feedback. *Proceedings of Presence 2009,* 1-6.

Hagen, M. C., Zald, D. H., Thornton, T. A., & Pardo, J. V. (2002). Somatosensory processing in the human inferior prefrontal cortex. *Journal of neurophysiology, 88*(3), 1400-1406.

Haggarty, C. J., Makdani, A., & McGlone, F. (2023). Affective touch: psychophysics, physiology and vicarious touch perception. In *Somatosensory Research Methods* (pp. 109-128). Springer.

Haggarty, C. J., Moore, D. J., Trotter, P. D., Hagan, R., McGlone, F. P., & Walker, S. C. (2021). Vicarious ratings of social touch the effect of age and autistic traits. *Scientific reports, 11*(1), 19336.

Hajcak, G., Dunning, J. P., & Foti, D. (2009). Motivated and controlled attention to emotion: time-course of the late positive potential. *Clinical Neurophysiology, 120*(3), 505-510.

Hawkley, L. C., Kocherginsky, M., Wong, J., Kim, J., & Cagney, K. A. (2014). Missing data in Wave 2 of NSHAP: Prevalence, predictors, and recommended treatment. *Journals* *of Gerontology Series B: Psychological Sciences and Social Sciences, 69*(Suppl_2), S38-S50.

Healey, J., & Picard, R. (2000). SmartCar: detecting driver stress. Proceedings 15th International Conference on Pattern Recognition. ICPR-2000,

Heatley Tejada, A., Dunbar, R., & Montero, M. (2020). Physical contact and loneliness: being touched reduces perceptions of loneliness. *Adaptive human behavior and physiology, 6*, 292-306.

Heidinger, T., & Richter, L. (2020). The effect of COVID-19 on loneliness in the elderly. An empirical comparison of pre-and peri-pandemic loneliness in community-dwelling elderly. *Frontiers in psychology, 11*, 585308.

Heiman, J. R., Long, J. S., Smith, S. N., Fisher, W. A., Sand, M. S., & Rosen, R. C. (2011). Sexual satisfaction and relationship happiness in midlife and older couples in five countries. *Archives of sexual behavior, 40*, 741-753.

Heinrichs, M., Baumgartner, T., Kirschbaum, C., & Ehlert, U. (2003). Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress. *Biological psychiatry, 54*(12), 1389-1398.

Henning-Smith, C. E., Gonzales, G., & Shippee, T. P. (2016). Barriers to timely medical care for older adults by disability status and household composition. *Journal of Disability Policy Studies, 27*(2), 116-127.

Herman, J. P., Nawreen, N., Smail, M. A., & Cotella, E. M. (2020). Brain mechanisms of HPA axis regulation: neurocircuitry and feedback in context Richard Kvetnansky lecture. *Stress, 23*(6), 617-632.

Hertenstein, M. J., Holmes, R., McCullough, M., & Keltner, D. (2009). The communication of emotion via touch. *Emotion, 9*(4), 566.

Hertenstein, M. J., Verkamp, J. M., Kerestes, A. M., & Holmes, R. M. (2006). The communicative functions of touch in humans, nonhuman primates, and rats: a review and synthesis of the empirical research. *Genetic, social, and general psychology monographs, 132*(1), 5-94.

Heslin, R., & Alper, T. (1983). Touch: A bonding gesture. *Nonverbal interaction*, 47-75.

Hjortskov, N., Rissén, D., Blangsted, A. K., Fallentin, N., Lundberg, U., & Søgaard, K. (2004). The effect of mental stress on heart rate variability and blood pressure during computer work. *European journal of applied physiology, 92,* 84-89.

Hoheisel, U., Unger, T., & Mense, S. (2005). Excitatory and modulatory effects of inflammatory cytokines and neurotrophins on mechanosensitive group IV muscle afferents in the rat. *Pain, 114*(1-2), 168-176.

Holle, H., Banissy, M. J., & Ward, J. (2013). Functional and structural brain differences associated with mirror-touch synaesthesia. *Neuroimage, 83*, 1041-1050.

Holt-Lunstad, J., Birmingham, W., & Jones, B. Q. (2008). Is there something unique about marriage? The relative impact of marital status, relationship quality, and network social support on ambulatory blood pressure and mental health. *Annals of behavioral medicine, 35*(2), 239-244.

Holt-Lunstad, J., Birmingham, W. A., & Light, K. C. (2008). Influence of a "warm touch" support enhancement intervention among married couples on ambulatory blood pressure, oxytocin, alpha amylase, and cortisol [Article]. *Psychosomatic Medicine, 70*(9), 976-985. https://doi.org/10.1097/PSY.0b013e318187aef7

Holt-Lunstad, J., Birmingham, W. A., & Light, K. C. (2008). Influence of a “warm touch” support enhancement intervention among married couples on ambulatory blood pressure, oxytocin, alpha amylase, and cortisol. *Psychosomatic Medicine, 70*(9), 976-985.

Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T., & Stephenson, D. (2015). Loneliness and social isolation as risk factors for mortality: a meta-analytic review. *Perspectives on psychological science, 10*(2), 227-237.

Holt-Lunstad, J., Smith, T. B., & Layton, J. B. (2010). Social relationships and mortality risk: a meta-analytic review. *PLoS medicine, 7*(7), e1000316.

Hopper, H. E., & Pinneau, S. R. (1957). Frequency of regurgitation in infancy as related to the amount of stimulation received from the mother. *Child Development*, 229-235.

Hornik, J., & Ellis, S. (1988). Strategies to secure compliance for a mall intercept interview. *Public Opinion Quarterly, 52*(4), 539-551.

Hou, W.-H., Chiang, P.-T., Hsu, T.-Y., Chiu, S.-Y., & Yen, Y.-C. (2010). Treatment effects of massage therapy in depressed people: a meta-analysis. *The Journal of clinical psychiatry, 71*(7), 21469.

Iannetti, G. D., Hughes, N. P., Lee, M. C., & Mouraux, A. (2008). Determinants of laser-evoked EEG responses: pain perception or stimulus saliency? *Journal of neurophysiology, 100*(2), 815-828.

Immanuel, S., Teferra, M. N., Baumert, M., & Bidargaddi, N. (2023). Heart rate variability for evaluating psychological stress changes in healthy adults: a scoping review. *Neuropsychobiology, 82*(4), 187-202.

Iriki, A., Tanaka, M., & Iwamura, Y. (1996). Attention-induced neuronal activity in the monkey somatosensory cortex revealed by pupillometrics. *Neuroscience research, 25*(2), 173-181.

Ishikura, T., Sato, W., Takamatsu, J., Yuguchi, A., Cho, S.-G., Ding, M., Yoshikawa, S., & Ogasawara, T. (2024). Delivery of pleasant stroke touch via robot in older adults. *Frontiers in psychology, 14*, 1292178.

Ishiyama, S., & Brecht, M. (2016). Neural correlates of ticklishness in the rat somatosensory cortex. *Science, 354*(6313), 757-760.

Ivry, R. B., & Mangun, G. R. (2014). *Cognitive Neuroscience: The biology of the mind*. Norton.

Jagannathan, R., Patel, S. A., Ali, M. K., & Narayan, K. V. (2019). Global updates on cardiovascular disease mortality trends and attribution of traditional risk factors. *Current diabetes reports, 19*, 1-12.

Jakubiak, B. K., & Feeney, B. C. (2016). Keep in touch: The effects of imagined touch support on stress and exploration. *Journal of Experimental Social Psychology, 65*, 59-67.

Jakubiak, B. K., & Feeney, B. C. (2017). Affectionate touch to promote relational, psychological, and physical well-being in adulthood: A theoretical model and review of the research. *Personality and Social Psychology Review, 21*(3), 228-252.

Jakubiak, B. K., & Feeney, B. C. (2019). Interpersonal touch as a resource to facilitate positive personal and relational outcomes during stress discussions. *Journal of Social and Personal Relationships, 36*(9), 2918-2936.

Jakubiak, B. K., Fuentes, J. D., & Feeney, B. C. (2021). Individual and relational differences in desire for touch in romantic relationships. *Journal of Social and Personal Relationships, 38*(7), 2029-2052.

Jean, A. D., & Stack, D. M. (2009). Functions of maternal touch and infants' affect during face-to-face interactions: New directions for the still-face. *Infant Behavior and Development, 32*(1), 123-128.

Jones, S. E., & Yarbrough, A. E. (1985). A naturalistic study of the meanings of touch. *Communications Monographs, 52*(1), 19-56.

Joule, R.-V., & Guéguen, N. (2007). Touch, compliance, and awareness of tactile contact. *Perceptual and Motor Skills, 104*(2), 581-588.

Jourard, S. M. (1966). An exploratory study of body-accessibility 1. *British Journal of Social and Clinical Psychology, 5*(3), 221-231.

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience & Biobehavioral Reviews, 35*(1), 2-16.

Kaiser, M. D., Yang, D. Y.-J., Voos, A. C., Bennett, R. H., Gordon, I., Pretzsch, C., Beam, D., Keifer, C., Eilbott, J., & McGlone, F. (2016). Brain mechanisms for processing affective (and nonaffective) touch are atypical in autism. *Cerebral cortex, 26*(6), 2705-2714.

Kalisch, T., Ragert, P., Schwenkreis, P., Dinse, H. R., & Tegenthoff, M. (2009). Impaired tactile acuity in old age is accompanied by enlarged hand representations in somatosensory cortex. *Cerebral cortex, 19*(7), 1530-1538.

Kandel, E. R., Schwartz, J. H., Jessell, T. M., Siegelbaum, S., Hudspeth, A. J., & Mack, S. (2000). *Principles of neural science* (Vol. 4). McGraw-hill New York.

Kane, H. S., McCall, C., Collins, N. L., & Blascovich, J. (2012). Mere presence is not enough: Responsive support in a virtual world. *Journal of Experimental Social Psychology, 48*(1), 37-44.

Karlamangla, A. S., Singer, B. H., McEwen, B. S., Rowe, J. W., & Seeman, T. E. (2002). Allostatic load as a predictor of functional decline: MacArthur studies of successful aging. *Journal of clinical epidemiology, 55*(7), 696-710.

Karlamangla, A. S., Singer, B. H., & Seeman, T. E. (2006). Reduction in allostatic load in older adults is associated with lower all-cause mortality risk: MacArthur studies of successful aging. *Psychosomatic Medicine, 68*(3), 500-507.

Keysers, C., & Gazzola, V. (2009). Expanding the mirror: vicarious activity for actions, emotions, and sensations. *Current opinion in neurobiology, 19*(6), 666-671.

Keysers, C., Kaas, J. H., & Gazzola, V. (2010). Somatosensation in social perception. *Nature reviews neuroscience, 11*(6), 417-428.

Keysers, C., Wicker, B., Gazzola, V., Anton, J.-L., Fogassi, L., & Gallese, V. (2004). A touching sight: SII/PV activation during the observation and experience of touch. *Neuron, 42*(2), 335-346.

Khorram, O. (1996). DHEA: a hormone with multiple effects. *Current opinion in obstetrics & gynecology, 8*(5), 351-354.

Kidd, T., Devine, S. L., & Walker, S. C. (2023). Affective touch and regulation of stress responses. *Health psychology review, 17*(1), 60-77.

Kim, H.-G., Cheon, E.-J., Bai, D.-S., Lee, Y. H., & Koo, B.-H. (2018). Stress and heart rate variability: a meta-analysis and review of the literature. *Psychiatry investigation, 15*(3), 235.

Kim, M.-K., Cho, J.-H., & Shin, H.-B. (2022). Recognition of tactile-related EEG signals generated by self-touch. 2022 10th International Winter Conference on Brain-Computer Interface (BCI),

Kirsch, L. P., Krahé, C., Blom, N., Crucianelli, L., Moro, V., Jenkinson, P. M., & Fotopoulou, A. (2018). Reading the mind in the touch: Neurophysiological specificity in the communication of emotions by touch. *Neuropsychologia, 116*, 136-149.

Kirsch, L. P., Von Mohr, M., Koukoutsakis, A., Fotopoulou, A., & von Mohr, M. (2024). Vicarious touch: a potential substitute for social touch during touch deprivation.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain research reviews, 29*(2-3), 169-195.

Klimesch, W. (2012). Alpha-band oscillations, attention, and controlled access to stored information. *Trends in cognitive sciences, 16*(12), 606-617.

Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience letters, 244*(2), 73-76.

Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: the inhibition–timing hypothesis. *Brain research reviews, 53*(1), 63-88.

Knyazev, G., Slobodskoj-Plusnin, J. Y., & Bocharov, A. (2009). Event-related delta and theta synchronization during explicit and implicit emotion processing. *Neuroscience, 164*(4), 1588-1600.

Knyazev, G. G. (2007). Motivation, emotion, and their inhibitory control mirrored in brain oscillations. *Neuroscience & Biobehavioral Reviews, 31*(3), 377-395.

Knyazev, G. G., Savostyanov, A. N., & Levin, E. A. (2006). Alpha synchronization and anxiety: implications for inhibition vs. alertness hypotheses. *International journal of Psychophysiology, 59*(2), 151-158.

Koole, S. L., Tjew A Sin, M., & Schneider, I. K. (2014). Embodied terror management: Interpersonal touch alleviates existential concerns among individuals with low self-esteem. *Psychological science, 25*(1), 30-37.

Korisky, A., Eisenberger, N. I., Nevat, M., Weissman-Fogel, I., & Shamay-Tsoory, S. G. (2020). A dual-brain approach for understanding the neuralmechanisms that underlie the comforting effects of social touch. *Cortex, 127*, 333-346.

Krahé, C., Fotopoulou, A., Hammond, C., Banissy, M. J., Koukoutsakis, A., & Jenkinson, P. M. (2023). The meaning of touch: Relational and individual variables shape emotions and intentions associated with imagined social touch. *European Journal of Social Psychology*.

Kraus, J., Roman, R., Lacinová, L., Lamoš, M., Brázdil, M., & Fredrikson, M. (2020). Imagery-induced negative affect, social touch and frontal EEG power band activity. *Scandinavian journal of psychology, 61*(6), 731-739.

Krause, C. M., Viemerö, V., Rosenqvist, A., Sillanmäki, L., & Åström, T. (2000). Relative electroencephalographic desynchronization and synchronization in humans to emotional film content: an analysis of the 4–6, 6–8, 8–10 and 10–12 Hz frequency bands. *Neuroscience letters, 286*(1), 9-12.

Kreuder, A. K., Scheele, D., Wassermann, L., Wollseifer, M., Stoffel-Wagner, B., Lee, M. R., Hennig, J., Maier, W., & Hurlemann, R. (2017). How the brain codes intimacy: The neurobiological substrates of romantic touch. *Human brain mapping, 38*(9), 4525-4534.

Kreuder, A. K., Wassermann, L., Wollseifer, M., Ditzen, B., Eckstein, M., Stoffel-Wagner, B., Hennig, J., Hurlemann, R., & Scheele, D. (2019). Oxytocin enhances the pain-relieving effects of social support in romantic couples [Article]. *Human brain mapping, 40*(1), 242-251. https://doi.org/10.1002/hbm.24368

Kuc, A., Skorokhodov, I., Semirechenko, A., Khayrullina, G., Maksimenko, V., Varlamov, A., Gordleeva, S., & Hramov, A. (2023). Oscillatory Responses to Tactile Stimuli of Different Intensity. *Sensors, 23*(22), 9286.

Kuehn, E., Haggard, P., Villringer, A., Pleger, B., & Sereno, M. I. (2018). Visually-driven maps in area 3b. *Journal of Neuroscience, 38*(5), 1295-1310.

Kuehn, E., Mueller, K., Turner, R., & Schütz-Bosbach, S. (2014). The functional architecture of S1 during touch observation described with 7 T fMRI. *Brain Structure and Function, 219*, 119-140.

Kuehn, E., Trampel, R., Mueller, K., Turner, R., & Schütz-Bosbach, S. (2013). Judging roughness by sight—A 7-tesla fMRI study on responsivity of the primary somatosensory cortex during observed touch of self and others. *Human brain mapping, 34*(8), 1882-1895.

Kulke, L., Feyerabend, D., & Schacht, A. (2020, 2020-February-28). A Comparison of the Affectiva iMotions Facial Expression Analysis Software With EMG for Identifying Facial Expressions of Emotion [Original Research]. *Frontiers in psychology, 11*. https://doi.org/10.3389/fpsyg.2020.00329

Kurzban, R. (2001). The social psychophysics of cooperation: Nonverbal communication in a public goods game. *Journal of Nonverbal Behavior, 25*, 241-259.

Laeng, B., Sirois, S., & Gredebäck, G. (2012). Pupillometry: A window to the preconscious? *Perspectives on psychological science, 7*(1), 18-27.

Lamm, C., Silani, G., & Singer, T. (2015). Distinct neural networks underlying empathy for pleasant and unpleasant touch. *Cortex, 70*, 79-89.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology, 30*(3), 261-273.

Lay, J. C., Gerstorf, D., Scott, S. B., Pauly, T., & Hoppmann, C. A. (2017). Neuroticism and extraversion magnify discrepancies between retrospective and concurrent affect reports. *Journal of Personality, 85*(6), 817-829.

Leahy, R., & Crews, D. E. (2012). Physiological dysregulation and somatic decline among elders: modeling, applying and re-interpreting allostatic load. *Collegium antropologicum, 36*(1), 11-22.

Leclerc, C. M., & Kensinger, E. A. (2011). Neural processing of emotional pictures and words: A comparison of young and older adults. *Developmental neuropsychology, 36*(4), 519-538.

Lee, C. R., & Margolis, D. J. (2016). Pupil dynamics reflect behavioral choice and learning in a go/nogo tactile decision-making task in mice. *Frontiers in behavioral neuroscience, 10*, 200.

Lee, J. E., & Cichy, K. E. (2020). Complex role of touch in social relationships for older adults' cardiovascular disease risk. *Research on Aging, 42*(7-8), 208-216.

Lee Masson, H., & Op de Beeck, H. (2018). Socio-affective touch expression database. *PLoS One, 13*(1), e0190921.

Leigh, D. (1977). Falsification, retrospective.

Leonard, J. A., Berkowitz, T., & Shusterman, A. (2014). The effect of friendly touch on delay-of-gratification in preschool children. *Quarterly Journal of Experimental Psychology, 67*(11), 2123-2133.

LePine, J. A., Podsakoff, N. P., & LePine, M. A. (2005). A meta-analytic test of the challenge stressor–hindrance stressor framework: An explanation for inconsistent relationships among stressors and performance. *Academy of management journal, 48*(5), 764-775.

Levine, S. (2005). Developmental determinants of sensitivity and resistance to stress. *Psychoneuroendocrinology, 30*(10), 939-946.

Liebler, C. A., & Sandefur, G. D. (2002). Gender differences in the exchange of social support with friends, neighbors, and co-workers at midlife. *Social Science Research, 31*(3), 364-391.

Light, K. C., Grewen, K. M., & Amico, J. A. (2005). More frequent partner hugs and higher oxytocin levels are linked to lower blood pressure and heart rate in premenopausal women. *Biological psychology, 69*(1), 5-21.

Lin, F. V., & Heffner, K. L. (2023). Autonomic nervous system flexibility for understanding brain aging. *Ageing Research Reviews*, 102016.

Lindgren, L., Rundgren, S., Winsö, O., Lehtipalo, S., Wiklund, U., Karlsson, M., Stenlund, H., Jacobsson, C., & Brulin, C. (2010). Physiological responses to touch massage in healthy volunteers. *Autonomic Neuroscience, 158*(1-2), 105-110.

Lindquist, K. A., & Barrett, L. F. (2008). Emotional complexity. *Handbook of emotions, 4*, 513-530.

Liu, D., Piao, Y., Ma, R., Zhang, Y., Guo, W., Zuo, L., Liu, W., Song, H., & Zhang, X. (2021). Actor and partner effects of touch: Touch-induced stress alleviation is influenced by perceived relationship quality of the couple. *Frontiers in psychology, 12*, 661438.

Lloyd, D., Di Pellegrino, G., & Roberts, N. (2004). Vicarious responses to pain in anterior cingulate cortex: is empathy a multisensory issue? *Cognitive, Affective, & Behavioral Neuroscience, 4*(2), 270-278.

Löken, L. S., Wessberg, J., McGlone, F., & Olausson, H. (2009). Coding of pleasant touch by unmyelinated afferents in humans. *Nature neuroscience, 12*(5), 547-548.

Lomas, T., Ivtzan, I., & Fu, C. H. (2015). A systematic review of the neurophysiology of mindfulness on EEG oscillations. *Neuroscience & Biobehavioral Reviews, 57*, 401-410.

Lund, I., Yu, L.-C., Uvnas-Moberg, K., Wang, J., Yu, C., Kurosawa, M., Agren, G., Rosen, A., Lekman, M., & Lundeberg, T. (2002). Repeated massage-like stimulation induces long-term effects on nociception: contribution of oxytocinergic mechanisms. *European Journal of Neuroscience, 16*(2), 330-338.

Lundberg, U., Kadefors, R., Melin, B., Palmerud, G., Hassmén, P., Engström, M., & Elfsberg Dohns, I. (1994). Psychophysiological stress and EMG activity of the trapezius muscle. *International journal of behavioral medicine, 1*(4), 354-370.

Lupien, S. J., Ouellet-Morin, I., Hupbach, A., Tu, M. T., Buss, C., Walker, D., Pruessner, J., & Mcewen, B. S. (2015). Beyond the stress concept: Allostatic load—A developmental biological and cognitive perspective. *Developmental psychopathology: Volume two: Developmental neuroscience,* 578-628.

Luque-Casado, A., Zabala, M., Morales, E., Mateo-March, M., & Sanabria, D. (2013). Cognitive performance and heart rate variability: the influence of fitness level. *PLoS One, 8*(2), e56935.

Lynch, J. J., Flaherty, L., Emrich, C., Mills, M. E., & Katcher, A. (1974). Effects of human contact on the heart activity of curarized patients in a shock-trauma unit. *American Heart Journal, 88*(2), 160-169.

M. Diamond, L. (2000). Passionate friendships among adolescent sexual-minority women. *Journal of Research on Adolescence, 10*(2), 191-209.

MacArthur, J., & MacArthur, C. (2000). Heart rate variability. *Retrieved January, 17*, 2003.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychological bulletin, 109*(2), 163.

Maeda, K., Kakigi, R., Hoshiyama, M., & Koyama, S. (1999). Topography of the secondary somatosensory cortex in humans: a magnetoencephalographic study. *Neuroreport, 10*(2), 301-306.

Magdin, M., Benko, Ľ., & Koprda, Š. (2019). A case study of facial emotion classification using affdex. *Sensors, 19*(9), 2140.

Maldjian, J. A. (1999). The sensory somatotopic map of the human hand demonstrated at 4 Tesla. *Neuroimage, 11*, 473-481.

Maner, J. K., DeWall, C. N., Baumeister, R. F., & Schaller, M. (2007). Does social exclusion motivate interpersonal reconnection? Resolving the" porcupine problem.". *Journal of Personality and Social Psychology, 92*(1), 42.

Maninger, N., Wolkowitz, O. M., Reus, V. I., Epel, E. S., & Mellon, S. H. (2009). Neurobiological and neuropsychiatric effects of dehydroepiandrosterone (DHEA) and DHEA sulfate (DHEAS). *Frontiers in neuroendocrinology, 30*(1), 65-91.

Martin, B. A. (2012). A stranger's touch: Effects of accidental interpersonal touch on consumer evaluations and shopping time. *Journal of Consumer Research, 39*(1), 174-184.

Masson, H. L., Van De Plas, S., Daniels, N., & de Beeck, H. O. (2018). The multidimensional representational space of observed socio-affective touch experiences. *Neuroimage, 175,* 297-314.

Mateo, M., Blasco-Lafarga, C., Martínez-Navarro, I., Guzmán, J. F., & Zabala, M. (2012). Heart rate variability and pre-competitive anxiety in BMX discipline. *European journal of applied physiology, 112,* 113-123.

Mather, M., Canli, T., English, T., Whitfield, S., Wais, P., Ochsner, K., John, D. G., & Carstensen, L. L. (2004). Amygdala responses to emotionally valenced stimuli in older and younger adults. *Psychological science, 15*(4), 259-263.

Mather, M., & Carstensen, L. L. (2005). Aging and motivated cognition: The positivity effect in attention and memory. *Trends in cognitive sciences, 9*(10), 496-502.

Mathewson, K. J., Jetha, M. K., Drmic, I. E., Bryson, S. E., Goldberg, J. O., Hall, G. B., Santesso, D. L., Segalowitz, S. J., & Schmidt, L. A. (2010). Autonomic predictors of Stroop performance in young and middle-aged adults. *International journal of Psychophysiology, 76*(3), 123-129.

Maulsby, R. L. (1971). An illustration of emotionally evoked theta rhythm in infancy: Hedonic hypersynchrony. *Electroencephalography and clinical neurophysiology, 31*(2), 157-165.

Mauss, D., Li, J., Schmidt, B., Angerer, P., & Jarczok, M. N. (2015). Measuring allostatic load in the workforce: a systematic review. *Industrial health, 53*(1), 5-20.

McCabe, C., Rolls, E. T., Bilderbeck, A., & McGlone, F. (2008). Cognitive influences on the affective representation of touch and the sight of touch in the human brain. *Social cognitive and affective neuroscience, 3*(2), 97-108.

McCaffery, J. M., Marsland, A. L., Strohacker, K., Muldoon, M. F., & Manuck, S. B. (2012). Factor structure underlying components of allostatic load. *PLoS One, 7*(10), e47246.

McCann, K., & McKenna, H. P. (1993). An examination of touch between nurses and elderly patients in a continuing care setting in Northern Ireland. *Journal of advanced nursing, 18*(5), 838-846.

McCrory, C., McLoughlin, S., Layte, R., NiCheallaigh, C., O'Halloran, A. M., Barros, H., Berkman, L. F., Bochud, M., Crimmins, E., & Farrell, M. (2023). Towards a consensus definition of allostatic load: a multi-cohort, multi-system, multi-biomarker individual participant data (IPD) meta-analysis. *Psychoneuroendocrinology*, 106117.

McDade, T. W., Burhop, J., & Dohnal, J. (2004). High-sensitivity enzyme immunoassay for C-reactive protein in dried blood spots. *Clinical chemistry, 50*(3), 652-654.

McDaniel, E., & Andersen, P. A. (1998). International patterns of interpersonal tactile communication: A field study. *Journal of Nonverbal Behavior, 22*, 59-75.

McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences, 840*(1), 33-44.

McEwen, B. S. (2000). Allostasis and allostatic load: implications for neuropsychopharmacology. *Neuropsychopharmacology, 22*(2), 108-124.

McEwen, B. S. (2003). Interacting mediators of allostasis and allostatic load: towards an understanding of resilience in aging. *Metabolism, 52*, 10-16.

McEwen, B. S. (2013). Allostasis and allostatic load: implications for neuropsychopharmacology. *Stress and the Brain*, 2-18.

McEwen, B. S., & Akil, H. (2020). Revisiting the stress concept: implications for affective disorders. *Journal of Neuroscience, 40*(1), 12-21.

McEwen, B. S., & Gianaros, P. J. (2011). Stress-and allostasis-induced brain plasticity. *Annual review of medicine, 62*(1), 431-445.

McEwen, B. S., & Stellar, E. (1993). Stress and the individual: Mechanisms leading to disease. *Archives of internal medicine, 153*(18), 2093-2101.

McGlone, F., Kelly, E. F., Trulsson, M., Francis, S. T., Westling, G., & Bowtell, R. (2002). Functional neuroimaging studies of human somatosensory cortex. *Behavioural brain research, 135*(1-2), 147-158.

McGlone, F., Olausson, H., Boyle, J. A., Jones-Gotman, M., Dancer, C., Guest, S., & Essick, G. (2012). Touching and feeling: differences in pleasant touch processing between glabrous and hairy skin in humans. *European Journal of Neuroscience, 35*(11), 1782-1788.

McGlone, F., & Reilly, D. (2010). The cutaneous sensory system. *Neuroscience & Biobehavioral Reviews, 34*(2), 148-159.

McGlone, F., Vallbo, A. B., Olausson, H., Loken, L., & Wessberg, J. (2007). Discriminative touch and emotional touch. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 61*(3), 173.

McGlone, F., Wessberg, J., & Olausson, H. (2014). Discriminative and affective touch: sensing and feeling. *Neuron, 82*(4), 737-755.

McIntyre, S., Nagi, S. S., McGlone, F., & Olausson, H. (2021). The effects of ageing on tactile function in humans. *Neuroscience, 464*, 53-58.

Measures, S. f. P. R. A. H. C. o. E., Boucsein, W., Fowles, D. C., Grimnes, S., Ben-Shakhar, G., Roth, W. T., Dawson, M. E., & Filion, D. L. (2012). Publication recommendations for electrodermal measurements. *Psychophysiology, 49*(8), 1017-1034.

Medalie, J. H., & Goldbourt, U. (1976). Angina pectoris among 10,000 men: II. Psychosocial and other risk factors as evidenced by a multivariate analysis of a five year incidence study. *The American journal of medicine, 60*(6), 910-921.

Mehrabian, A. (1969). Significance of posture and position in the communication of attitude and status relationships. *Psychological bulletin, 71*(5), 359.

Meijer, L. L., Ruis, C., van der Smagt, M. J., Scherder, E. J., & Dijkerman, H. C. (2022). Neural basis of affective touch and pain: A novel model suggests possible targets for pain amelioration. *Journal of Neuropsychology, 16*(1), 38-53.

Mendelowitz, D. (1999). Advances in parasympathetic control of heart rate and cardiac function. *Physiology, 14*(4), 155-161.

Mense, S., & Meyer, H. (1985). Different types of slowly conducting afferent units in cat skeletal muscle and tendon. *The Journal of physiology, 363*(1), 403-417.

Michail, G., Dresel, C., Witkovský, V., Stankewitz, A., & Schulz, E. (2016). Neuronal oscillations in various frequency bands differ between pain and touch. *Frontiers in human neuroscience, 10*, 182.

Mickelson, K. D., & Kubzansky, L. D. (2003). Social distribution of social support: The mediating role of life events. *American journal of community psychology, 32*, 265-281.

Mikulincer, M., Gillath, O., & Shaver, P. R. (2002). Activation of the attachment system in adulthood: threat-related primes increase the accessibility of mental representations of attachment figures. *Journal of Personality and Social Psychology, 83*(4), 881.

Mikulincer, M., Shaver, P. R., & Pereg, D. (2003). Attachment theory and affect regulation: The dynamics, development, and cognitive consequences of attachment-related strategies. *Motivation and emotion, 27*(2), 77-102.

Mill, A., Realo, A., & Allik, J. (2016). Retrospective ratings of emotions: The effects of age, daily tiredness, and personality. *Frontiers in psychology, 6*, 2020.

Mitchell, D. J., McNaughton, N., Flanagan, D., & Kirk, I. J. (2008). Frontal-midline theta from the perspective of hippocampal "theta". *Progress in neurobiology, 86*(3), 156-185.

Moberg, K. U., Handlin, L., & Petersson, M. (2020, 2020/11/01/). Neuroendocrine mechanisms involved in the physiological effects caused by skin-to-skin contact – With a particular focus on the oxytocinergic system. *Infant Behavior and Development, 61*, 101482. https://doi.org/https://doi.org/10.1016/j.infbeh.2020.101482

Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: a meta-analysis of 125 human fMRI studies. *Neuroscience & Biobehavioral Reviews, 36*(1), 341-349.

Morioka, M., Whitehouse, D. J., & Griffin, M. J. (2008). Vibrotactile thresholds at the fingertip, volar forearm, large toe, and heel. *Somatosensory & motor research, 25*(2), 101-112.

Morrison, I. (2016a). ALE meta-analysis reveals dissociable networks for affective and discriminative aspects of touch. *Human brain mapping, 37*(4), 1308-1320.

Morrison, I. (2016b). Keep calm and cuddle on: social touch as a stress buffer. *Adaptive human behavior and physiology, 2,* 344-362.

Morrison, I. (2023). Touching to connect, explore, and explain: How the human brain makes social touch meaningful. *The Senses and Society, 18*(2), 92-109.

Morrison, I., Lloyd, D., Di Pellegrino, G., & Roberts, N. (2004). Vicarious responses to pain in anterior cingulate cortex: is empathy a multisensory issue? *Cognitive, Affective, & Behavioral Neuroscience, 4*(2), 270-278.

Morrison, I., Löken, L. S., & Olausson, H. (2010). The skin as a social organ. *Experimental brain research, 204,* 305-314.

Morriss, J., Bell, T., Johnstone, T., Van Reekum, C. M., & Hill, J. (2019). Social domain based modulation of neural responses to threat: The different roles of romantic partners versus friends. *Social Neuroscience, 14*(4), 398-408.

Mueller, V., Richer, R., Henrich, L., Berger, L., Gelardi, A., Jaeger, K. M., Eskofier, B. M., & Rohleder, N. (2022). The stroop competition: a social-evaluative stroop test for acute stress induction. 2022 IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI),

Murphy, S. L., Kochanek, K. D., Xu, J., & Arias, E. (2021). Mortality in the united states, 2020.

Nagy, E., Farkas, T., Guy, F., & Stafylarakis, A. (2020). Effects of handshake duration on other nonverbal behavior. *Perceptual and Motor Skills, 127*(1), 52-74.

Navyte, G., Gillmeister, H., & Kumari, M. (2024). Interpersonal touch and the importance of romantic partners for older adults' neuroendocrine health. *Psychoneuroendocrinology, 159*, 106414.

Nelson, E. E., & Panksepp, J. (1998). Brain substrates of infant–mother attachment: contributions of opioids, oxytocin, and norepinephrine. *Neuroscience & Biobehavioral Reviews, 22*(3), 437-452.

Nguyen, T., Abney, D. H., Salamander, D., Bertenthal, B. I., & Hoehl, S. (2021). Proximity and touch are associated with neural but not physiological synchrony in naturalistic mother-infant interactions. *Neuroimage, 244*, 118599.

Nilsen, W. J., & Vrana, S. R. (1998). Some touching situations: The relationship between gender and contextual variables in cardiovascular responses to human touch. *Annals of behavioral medicine, 20*(4), 270-276.

Noone, C., & McKenna-Plumley, P. E. (2022). Lonely for touch? A narrative review on the role of touch in loneliness. *Behaviour Change, 39*(3), 157-167.

Nordin, M. (1990). Low-threshold mechanoreceptive and nociceptive units with unmyelinated (C) fibres in the human supraorbital nerve. *The Journal of physiology, 426*(1), 229-240.

Norman, D., & Shallice, T. (2000). Attention to action: Willed and automatic control of behaviour.

Nunez, P. L. (2000). Toward a quantitative description of large-scale neocortical dynamic function and EEG. *Behavioral and Brain Sciences, 23*(3), 371-398.

Nussinovitch, U., Elishkevitz, K. P., Katz, K., Nussinovitch, M., Segev, S., Volovitz, B., & Nussinovitch, N. (2011). Reliability of ultra-short ECG indices for heart rate variability. *Annals of Noninvasive Electrocardiology, 16*(2), 117-122.

Nye, C. D., Newman, D. A., & Joseph, D. L. (2010). Never say ‘‘always’’? Extreme item wording effects on scalar invariance and item response curves. *Organizational Research Methods, 13*(4), 806-830.

O’Muircheartaigh, C., Eckman, S., & Smith, S. (2009). Statistical design and estimation for the national social life, health, and aging project. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 64*(suppl_1), i12-i19.

Ojanlatva, A. (1994). Touch as a human tool. *Medical Teacher, 16*(4), 347-353.

Olausson, H., Lamarre, Y., Backlund, H., Morin, C., Wallin, B., Starck, G., Ekholm, S., Strigo, I., Worsley, K., & Vallbo, Å. (2002). Unmyelinated tactile afferents signal touch and project to insular cortex. *Nature neuroscience, 5*(9), 900-904.

Olausson, H., Wessberg, J., McGlone, F., & Vallbo, Å. (2010). The neurophysiology of unmyelinated tactile afferents. *Neuroscience & Biobehavioral Reviews, 34*(2), 185-191.

Olausson, H. W., Cole, J., Vallbo, Å., McGlone, F., Elam, M., Krämer, H. H., Rylander, K., Wessberg, J., & Bushnell, M. C. (2008). Unmyelinated tactile afferents have opposite effects on insular and somatosensory cortical processing. *Neuroscience letters, 436*(2), 128-132.

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: an integrative review of ERP findings. *Biological psychology, 77*(3), 247-265.

ONS. (2021). *Families and households in the UK: 2020* Office for National Statistics. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/bulletins/familiesandhouseholds/2020

Packheiser, J., Berretz, G., Rook, N., Bahr, C., Schockenhoff, L., Güntürkün, O., & Ocklenburg, S. (2021). Investigating real-life emotions in romantic couples: a mobile EEG study. *Scientific reports, 11*(1), 1142.

Packheiser, J., Hartmann, H., Fredriksen, K., Gazzola, V., Keysers, C., & Michon, F. (2023). The physical and mental health benefits of touch interventions: A comparative systematic review and multivariate meta-analysis. *medRxiv*, 2023.2006.2020.23291651. https://doi.org/10.1101/2023.06.20.23291651

Packheiser, J., Hartmann, H., Fredriksen, K., Gazzola, V., Keysers, C., & Michon, F. (2024a, 2024/06/01). A systematic review and multivariate meta-analysis of the physical and mental health benefits of touch interventions. *Nature Human Behaviour, 8*(6), 1088-1107. https://doi.org/10.1038/s41562-024-01841-8

Packheiser, J., Hartmann, H., Fredriksen, K., Gazzola, V., Keysers, C., & Michon, F. (2024b). A systematic review and multivariate meta-analysis of the physical and mental health benefits of touch interventions. *Nature Human Behaviour,* 1-20.

Palgi, Y., Shrira, A., Ring, L., Bodner, E., Avidor, S., Bergman, Y., Cohen-Fridel, S., Keisari, S., & Hoffman, Y. (2020). The loneliness pandemic: Loneliness and other concomitants of depression, anxiety and their comorbidity during the COVID-19 outbreak. *Journal of affective disorders, 275*, 109-111.

Pansara, Z., Navyte, G., Gillmeister, H., Cinel, C., & De Feo, V. (2024). Towards an Accurate Measure of Emotional Pupil Dilation Responses: A Model for Removing the Effect of Luminosity. *IEEE MetroXRAINE, 1*(1).

Papathanassoglou, E. D., & Mpouzika, M. D. (2012). Interpersonal touch: physiological effects in critical care. *Biological Research for Nursing, 14*(4), 431-443.

Parkinson, B., Briner, R. B., Reynolds, S., & Totterdell, P. (1995). Time frames for mood: Relations between momentary and generalized ratings of affect. *Personality and Social Psychology Bulletin, 21*(4), 331-339.

Partala, T., & Surakka, V. (2003). Pupil size variation as an indication of affective processing. *International journal of human-computer studies, 59*(1-2), 185-198.

Pawling, R., Cannon, P. R., McGlone, F. P., & Walker, S. C. (2017). C-tactile afferent stimulating touch carries a positive affective value. *PLoS One, 12*(3), e0173457.

Pawling, R., McGlone, F., & Walker, S. C. (2024). High Frequency Heart Rate Variability is Associated with Sensitivity to Affective Touch. *Physiology & behavior*, 114600.

Pedell, S., Vetere, F., Kulik, L., Ozanne, E., & Gruner, A. (2010). Social isolation of older people: the role of domestic technologies. Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction,

Pehlivanoğlu, B., Durmazlar, N., & Balkancı, D. (2005). Computer adapted Stroop colour-word conflict test as a laboratory stress model. *Journal of Clinical Practice and Research, 27*(2), 58.

Peled-Avron, L., Goldstein, P., Yellinek, S., Weissman-Fogel, I., & Shamay-Tsoory, S. (2018). Empathy during consoling touch is modulated by mu-rhythm: An EEG study. *Neuropsychologia, 116*, 68-74.

Peled-Avron, L., Levy-Gigi, E., Richter-Levin, G., Korem, N., & Shamay-Tsoory, S. G. (2016). The role of empathy in the neural responses to observed human social touch. *Cognitive, Affective, & Behavioral Neuroscience, 16*, 802-813.

Peled-Avron, L., & Shamay-Tsoory, S. G. (2017). Don't touch me! autistic traits modulate early and late ERP components during visual perception of social touch. *Autism Research, 10*(6), 1141-1154.

Pendleton, D. M., Sakalik, M. L., Moore, M. L., & Tomporowski, P. D. (2016). Mental engagement during cognitive and psychomotor tasks: Effects of task type, processing demands, and practice. *International journal of Psychophysiology, 109*, 124-131.

Pérez-Valenzuela, C., Terreros, G., & Dagnino-Subiabre, A. (2019). Effects of stress on the auditory system: an approach to study a common origin for mood disorders and dementia. *Reviews in the Neurosciences, 30*(3), 317-324.

Perini, I., Olausson, H., & Morrison, I. (2015). Seeking pleasant touch: neural correlates of behavioral preferences for skin stroking. *Frontiers in behavioral neuroscience, 9*, 8.

Perry, A., Bentin, S., Bartal, I. B.-A., Lamm, C., & Decety, J. (2010). “Feeling” the pain of those who are different from us: Modulation of EEG in the mu/alpha range. *Cognitive, Affective, & Behavioral Neuroscience, 10*, 493-504.

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: perceptual illusion of body swapping. *PLoS One, 3*(12), e3832.

Phelan, J. E. (2009). Exploring the use of touch in the psychotherapeutic setting: A phenomenological review. *Psychotherapy: Theory, Research, Practice, Training, 46*(1), 97.

Pino, L., González-Vélez, A. E., Prieto-Flores, M. E., Ayala, A., Fernandez-Mayoralas, G., Rojo-Perez, F., Martinez-Martin, P., & Forjaz, M. J. (2014). Self-perceived health and quality of life by activity status in community-dwelling older adults. *Geriatrics & gerontology international, 14*(2), 464-473.

Pisano, M. D., Wall, S. M., & Foster, A. (1986). Perceptions of nonreciprocal touch in romantic relationships. *Journal of Nonverbal Behavior, 10*, 29-40.

Pisoni, A., Lauro, L. J. R., Vergallito, A., Maddaluno, O., & Bolognini, N. (2018). Cortical dynamics underpinning the self-other distinction of touch: A TMS-EEG study. *Neuroimage, 178*, 475-484.

Pitesa, M., & Gelfand, M. J. (2023). Going beyond Western, Educated, Industrialized, Rich, and Democratic (WEIRD) samples and problems in organizational research. *Organizational Behavior and Human Decision Processes, 174*, 104212.

Poerio, G. L., Blakey, E., Hostler, T. J., & Veltri, T. (2018). More than a feeling: Autonomous sensory meridian response (ASMR) is characterized by reliable changes in affect and physiology. *PLoS One, 13*(6), e0196645.

Porges, S. W. (2007). The polyvagal perspective. *Biological psychology, 74*(2), 116-143.

PP, R. (1964). Human experimentation. Code of ethics of the world medical association. Declaration of Helsinki. *British medical journal, 2*(5402), 177-177.

Punyanunt-Carter, N. M., Wrench, J. S., Suny, E., & Paltz, N. (2009). Development and validity testing of a measure of touch deprivation. *Hum. Commun, 12*, 67-76.

Pyszczynski, T., Greenberg, J., & Holt, K. (1985). Maintaining consistency between self-serving beliefs and available data: A bias in information evaluation. *Personality and Social Psychology Bulletin, 11*(2), 179-190.

Qin, S., Hermans, E. J., Van Marle, H. J., & Fernández, G. (2012). Understanding low reliability of memories for neutral information encoded under stress: alterations in memory-related activation in the hippocampus and midbrain. *Journal of Neuroscience, 32*(12), 4032-4041.

Rakita, A., Nikolić, N., Mildner, M., Matiasek, J., & Elbe-Bürger, A. (2020). Re-epithelialization and immune cell behaviour in an ex vivo human skin model. *Scientific reports, 10*(1), 1.

Randall, A. K., & Bodenmann, G. (2009). The role of stress on close relationships and marital satisfaction. *Clinical psychology review, 29*(2), 105-115.

Ray, W. J., & Cole, H. W. (1985). EEG alpha activity reflects attentional demands, and beta activity reflects emotional and cognitive processes. *Science, 228*(4700), 750-752.

Reddan, M. C., Young, H., Falkner, J., López-Solà, M., & Wager, T. D. (2020). Touch and social support influence interpersonal synchrony and pain. *Social cognitive and affective neuroscience, 15*(10), 1064-1075.

Ree, A., Mayo, L. M., Leknes, S., & Sailer, U. (2019). Touch targeting C-tactile afferent fibers has a unique physiological pattern: A combined electrodermal and facial electromyography study. *Biological psychology, 140*, 55-63.

Reis, H. T., & Patrick, B. C. (1996). Attachment and intimacy: Component processes. In *Social psychology: Handbook of basic principles.* (pp. 523-563). The Guilford Press.

Remland, M. S., Jones, T. S., & Brinkman, H. (1995). Interpersonal distance, body orientation, and touch: Effects of culture, gender, and age. *The Journal of Social Psychology, 135*(3), 281-297.

Ren, P., Barreto, A., Huang, J., Gao, Y., Ortega, F. R., & Adjouadi, M. (2014). Off-line and on-line stress detection through processing of the pupil diameter signal. *Annals of biomedical engineering, 42*, 162-176.

Renaud, P., & Blondin, J.-P. (1997). The stress of Stroop performance: Physiological and emotional responses to color–word interference, task pacing, and pacing speed. *International journal of Psychophysiology, 27*(2), 87-97.

Rigato, S., Banissy, M. J., Romanska, A., Thomas, R., van Velzen, J., & Bremner, A. J. (2019). Cortical signatures of vicarious tactile experience in four-month-old infants. *Developmental cognitive neuroscience, 35*, 75-80.

Rigato, S., Bremner, A. J., Gillmeister, H., & Banissy, M. J. (2019). Interpersonal representations of touch in somatosensory cortex are modulated by perspective. *Biological psychology, 146*, 107719.

Ripin, R., & Lazarsfeld, P. F. (1937). The tactile-kinaesthetic perception of fabrics with emphasis on their relative pleasantness. *Journal of Applied Psychology, 21*(2), 198.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature reviews neuroscience, 2*(9), 661-670.

Rolls, E. T., O'Doherty, J., Kringelbach, M. L., Francis, S., Bowtell, R., & McGlone, F. (2003). Representations of pleasant and painful touch in the human orbitofrontal and cingulate cortices. *Cerebral cortex, 13*(3), 308-317.

Rook, K. S. (2001, 2001/04/01). Emotional Health and Positive Versus Negative Social Exchanges: A Daily Diary Analysis. *Applied Developmental Science, 5*(2), 86-97. https://doi.org/10.1207/S1532480XADS0502_4

Rosamond, W., Flegal, K., Friday, G., Furie, K., Go, A., Greenlund, K., Haase, N., Ho, M., Howard, V., & Kissela, B. (2007). Heart disease and stroke statistics—2007 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation, 115*(5), e69-e171.

Routasalo, P. (1999). Physical touch in nursing studies: a literature review. *Journal of advanced nursing, 30*(4), 843-850.

Ruffman, T., Henry, J. D., Livingstone, V., & Phillips, L. H. (2008). A meta-analytic review of emotion recognition and aging: Implications for neuropsychological models of aging. *Neuroscience & Biobehavioral Reviews, 32*(4), 863-881.

Russo, V., Ottaviani, C., & Spitoni, G. F. (2020). Affective touch: A meta-analysis on sex differences. *Neuroscience & Biobehavioral Reviews, 108*, 445-452.

Saarinen, A., Harjunen, V., Jasinskaja-Lahti, I., Jääskeläinen, I. P., & Ravaja, N. (2021). Social touch experience in different contexts: A review. *Neuroscience & Biobehavioral Reviews, 131*, 360-372.

Sailer, U., & Ackerley, R. (2019). Exposure shapes the perception of affective touch. *Developmental cognitive neuroscience, 35*, 109-114.

Sailer, U., Friedrich, Y., Asgari, F., Hassenzahl, M., & Croy, I. (2024). Determinants for positive and negative experiences of interpersonal touch: context matters. *Cognition and Emotion*, 1-22.

Sailer, U., & Leknes, S. (2022). Meaning makes touch affective. *Current Opinion in Behavioral Sciences, 44*, 101099.

Sapolsky, R. M. (2021). Glucocorticoids, the evolution of the stress-response, and the primate predicament. *Neurobiology of Stress, 14*, 100320.

Satish, P., Muralikrishnan, K., & Balasubramanian, K. (2015). Heart rate variability changes during stroop color and word test among genders. *Indian J Physiol Pharmacol, 59*(1), 9-15.

Saunders, B., Riesel, A., Klawohn, J., & Inzlicht, M. (2018). Interpersonal touch enhances cognitive control: A neurophysiological investigation. *Journal of Experimental Psychology: General, 147*(7), 1066.

Savikko, N., Routasalo, P., Tilvis, R. S., Strandberg, T. E., & Pitkälä, K. H. (2005). Predictors and subjective causes of loneliness in an aged population. *Archives of gerontology and geriatrics, 41*(3), 223-233.

Saxe, R., Jamal, N., & Powell, L. (2006). My body or yours? The effect of visual perspective on cortical body representations. *Cerebral cortex, 16*(2), 178-182.

Sbarra, D. A., & Hazan, C. (2008). Coregulation, dysregulation, self-regulation: An integrative analysis and empirical agenda for understanding adult attachment, separation, loss, and recovery. *Personality and Social Psychology Review, 12*(2), 141-167.

Schaefer, M., Heinze, H.-J., & Rotte, M. (2012). Embodied empathy for tactile events: interindividual differences and vicarious somatosensory responses during touch observation. *Neuroimage, 60*(2), 952-957.

Scharf, T., & de Jong Gierveld, J. (2008). Loneliness in urban neighbourhoods: an Anglo-Dutch comparison. *European Journal of Ageing, 5*(2), 103-115.

Scheier, M. F., & Carver, C. S. (1985). Optimism, coping, and health: assessment and implications of generalized outcome expectancies. *Health Psychology, 4*(3), 219.

Schielzeth, H., Dingemanse, N. J., Nakagawa, S., Westneat, D. F., Allegue, H., Teplitsky, C., Réale, D., Dochtermann, N. A., Garamszegi, L. Z., & Araya-Ajoy, Y. G. (2020). Robustness of linear mixed-effects models to violations of distributional assumptions. *Methods in ecology and evolution, 11*(9), 1141-1152.

Schirmer, A. (2018). Is the voice an auditory face? An ALE meta-analysis comparing vocal and facial emotion processing. *Social cognitive and affective neuroscience, 13*(1), 1-13.

Schirmer, A., Cham, C., Zhao, Z., & Croy, I. (2023). What makes touch comfortable? An examination of touch giving and receiving in two cultures. *Personality and Social Psychology Bulletin, 49*(9), 1392-1407.

Schirmer, A., Chiu, M. H., & Croy, I. (2021). More than one kind: Different sensory signatures and functions divide affectionate touch. *Emotion, 21*(6), 1268.

Schirmer, A., & McGlone, F. (2019). A touching sight: EEG/ERP correlates for the vicarious processing of affectionate touch. *Cortex, 111,* 1-15.

Schneider, E., Hopf, D., Aguilar-Raab, C., Scheele, D., Neubauer, A. B., Sailer, U., Hurlemann, R., Eckstein, M., & Ditzen, B. (2023). Affectionate touch and diurnal oxytocin levels: An ecological momentary assessment study. *Elife, 12,* e81241.

Schroeter, M. L., Zysset, S., Kupka, T., Kruggel, F., & Von Cramon, D. Y. (2002). Near-infrared spectroscopy can detect brain activity during a color–word matching Stroop task in an event-related design. *Human brain mapping, 17*(1), 61-71.

Schulkin, J. (2003). *Rethinking homeostasis: Allostatic regulation in physiology and pathophysiology*. MIT Press.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: the late positive potential is modulated by motivational relevance. *Psychophysiology, 37*(2), 257-261.

Schutter, D. J., Putman, P., Hermans, E., & van Honk, J. (2001). Parietal electroencephalogram beta asymmetry and selective attention to angry facial expressions in healthy human subjects. *Neuroscience letters*, *314*(1-2), 13-16.

Seeman, M., Merkin, S. S., Karlamangla, A., Koretz, B., & Seeman, T. (2014). Social status and biological dysregulation: the “status syndrome” and allostatic load. *Social Science & Medicine, 118*, 143-151.

Seeman, T. E., Berkman, L. F., Kohout, F., Lacroix, A., Glynn, R., & Blazer, D. (1993). Intercommunity variations in the association between social ties and mortality in the elderly: A comparative analysis of three communities. *Annals of epidemiology, 3*(4), 325-335.

Seeman, T. E., McEwen, B. S., Rowe, J. W., & Singer, B. H. (2001). Allostatic load as a marker of cumulative biological risk: MacArthur studies of successful aging. *Proceedings of the National Academy of Sciences, 98*(8), 4770-4775.

Seeman, T. E., Singer, B. H., Rowe, J. W., Horwitz, R. I., & McEwen, B. S. (1997). Price of adaptation—allostatic load and its health consequences: MacArthur studies of successful aging. *Archives of internal medicine, 157*(19), 2259-2268.

Sehlstedt, I., Ignell, H., Backlund Wasling, H., Ackerley, R., Olausson, H., & Croy, I. (2016). Gentle touch perception across the lifespan. *Psychology and aging, 31*(2), 176.

Sened, H., Levin, C., Shehab, M., Eisenberger, N., & Shamay-Tsoory, S. (2023). I wanna hold your hand: Handholding is preferred over gentle stroking for emotion regulation. *PLoS One, 18*(4), e0284161.

Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Frontiers in public health, 5*, 258.

Shagass, G. (1972). Electrical activity of the brain. *Handbook of psychophysiology*, 263-328.

Shankar, A., McMunn, A., Demakakos, P., Hamer, M., & Steptoe, A. (2017). Social isolation and loneliness: Prospective associations with functional status in older adults. *Health Psychology, 36*(2), 179.

Simoes, C., Jensen, O., Parkkonen, L., & Hari, R. (2003). Phase locking between human primary and secondary somatosensory cortices. *Proceedings of the National Academy of Sciences, 100*(5), 2691-2694.

Singer, T., Seymour, B., O'doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science, 303*(5661), 1157-1162.

Singh, H., Bauer, M., Chowanski, W., Sui, Y., Atkinson, D., Baurley, S., Fry, M., Evans, J., & Bianchi-Berthouze, N. (2014). The brain's response to pleasant touch: An EEG investigation of tactile caressing. *Frontiers in human neuroscience, 8*, 893.

Sirois, S., & Brisson, J. (2014). Pupillometry. *Wiley Interdisciplinary Reviews: Cognitive Science, 5*(6), 679-692.

Šiška, E. (2002). The Stroop Colour-Word Test in Psychology and Biomedicine. *Acta Universitatis Palackianae Olomucensis. Gymnica, 32*(1).

Smit, S., Moerel, D., Zopf, R., & Rich, A. N. (2023). Vicarious touch: overlapping neural patterns between seeing and feeling touch. *Neuroimage, 278,* 120269.

Sorokowska, A., Saluja, S., Sorokowski, P., Frąckowiak, T., Karwowski, M., Aavik, T., Akello, G., Alm, C., Amjad, N., & Anjum, A. (2021). Affective interpersonal touch in close relationships: A cross-cultural perspective. *Personality and Social Psychology Bulletin, 47*(12), 1705-1721.

Spitoni, G. F., Zingaretti, P., Giovanardi, G., Antonucci, G., Galati, G., Lingiardi, V., Cruciani, G., Titone, G., & Boccia, M. (2020). Disorganized attachment pattern affects the perception of affective touch. *Scientific reports, 10*(1), 9658.

Stack, D. M., & Muir, D. W. (1990). Tactile stimulation as a component of social interchange: New interpretations for the still-face effect. *British Journal of Developmental Psychology, 8*(2), 131-145.

Stein, N., & Sanfilipo, M. (1985). Depression and the wish to be held. *Journal of clinical psychology, 41*(1), 3-9.

Steinhauer, S. R., Siegle, G. J., Condray, R., & Pless, M. (2004). Sympathetic and parasympathetic innervation of pupillary dilation during sustained processing. *International journal of Psychophysiology, 52*(1), 77-86.

Stephen, R., & Zweigenhaft, R. L. (1986). The effect on tipping of a waitress touching male and female customers. *The Journal of Social Psychology, 126*(1), 141-142.

Sterling, P. (1988). Allostasis: a new paradigm to explain arousal pathology. *Handbook of life stress, cognition and health*.

Sterling, P., & Eyer, J. (1988). Allostasis: a new paradigm to explain arousal pathology. In ‘Handbook of life stress, cognition and health’.(Eds S Fisher, J Reason) pp. 629–649.

Stern, R. M., Ray, W. J., & Quigley, K. S. (2001). *Psychophysiological recording*. Oxford University Press, USA.

Stevens, J. C., & Choo, K. K. (1996). Spatial acuity of the body surface over the life span. *Somatosensory & motor research, 13*(2), 153-166.

Stevens, J. C., & Patterson, M. Q. (1995). Dimensions of spatial acuity in the touch sense: changes over the life span. *Somatosensory & motor research, 12*(1), 29-47.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of experimental psychology, 18*(6), 643.

Stroop, J. R. (1992). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology: General, 121*(1), 15.

Sue Carter, C. (1998, 1998/11/01/). NEUROENDOCRINE PERSPECTIVES ON SOCIAL ATTACHMENT AND LOVE. *Psychoneuroendocrinology, 23*(8), 779-818. https://doi.org/https://doi.org/10.1016/S0306-4530(98)00055-9

Sugenoya, J., Iwase, S., Mano, T., & Ogawa, T. (1990). Identification of sudomotor activity in cutaneous sympathetic nerves using sweat expulsion as the effector response. *European journal of applied physiology and occupational physiology, 61*, 302-308.

Sumich, A., Heym, N., Sarkar, M., Burgess, T., French, J., Hatch, L., & Hunter, K. (2022). The power of touch: The effects of havening touch on subjective distress, mood, brain function, and psychological health. *Psychology & Neuroscience, 15*(4), 332.

Sussman, N. M., & Rosenfeld, H. M. (1978). Touch, justification, and sex: Influences on the aversiveness of spatial violations. *The Journal of Social Psychology, 106*(2), 215-225.

Suvilehto, J. T., Glerean, E., Dunbar, R. I., Hari, R., & Nummenmaa, L. (2015). Topography of social touching depends on emotional bonds between humans. *Proceedings of the National Academy of Sciences, 112*(45), 13811-13816.

Suvilehto, J. T., Nummenmaa, L., Harada, T., Dunbar, R. I., Hari, R., Turner, R., Sadato, N., & Kitada, R. (2019). Cross-cultural similarity in relationship-specific social touching. *Proceedings of the Royal Society B, 286*(1901), 20190467.

Suzuki, T., Suzuki, N., Daynes, R. A., & Engleman, E. G. (1991). Dehydroepiandrosterone enhances IL2 production and cytotoxic effector function of human T cells. *Clinical immunology and immunopathology, 61*(2), 202-211.

Taelman, J., Vandeput, S., Vlemincx, E., Spaepen, A., & Van Huffel, S. (2011). Instantaneous changes in heart rate regulation due to mental load in simulated office work. *European journal of applied physiology, 111*, 1497-1505.

Tanaka, G. K., Peressutti, C., Teixeira, S., Cagy, M., Piedade, R., Nardi, A. E., Ribeiro, P., & Velasques, B. (2014). Lower trait frontal theta activity in mindfulness meditators. *Arquivos de neuro-psiquiatria, 72*(9), 687-693.

Tang, Y., Benusiglio, D., Lefevre, A., Hilfiger, L., Althammer, F., Bludau, A., Hagiwara, D., Baudon, A., Darbon, P., Schimmer, J., Kirchner, M. K., Roy, R. K., Wang, S., Eliava, M., Wagner, S., Oberhuber, M., Conzelmann, K. K., Schwarz, M., Stern, J. E., Leng, G., Neumann, I. D., Charlet, A., & Grinevich, V. (2020). Social touch promotes interfemale communication via activation of parvocellular oxytocin neurons [Article]. *Nature neuroscience, 23*(9), 1125-1137. https://doi.org/10.1038/s41593-020-0674-y

Taylor-Clarke, M., Kennett, S., & Haggard, P. (2002). Vision modulates somatosensory cortical processing. *Current Biology, 12*(3), 233-236.

Taylor, R. J., Mouzon, D. M., Nguyen, A. W., & Chatters, L. M. (2016). Reciprocal family, friendship and church support networks of African Americans: Findings from the National Survey of American Life. *Race and Social Problems, 8*, 326-339.

Team, R. C. (2021). R: A Language and Environment for Statistical Computing. *R Foundation for Statistical Computing, Vienna, Austria*. https://www.R-project.org/

Thayer, J. F., & Brosschot, J. F. (2005). Psychosomatics and psychopathology: looking up and down from the brain. *Psychoneuroendocrinology, 30*(10), 1050-1058.

Thomas, P. A., & Kim, S. (2021). Lost touch? Implications of physical touch for physical health. *The Journals of Gerontology: Series B, 76*(3), e111-e115.

Thompson, E. H., & Hampton, J. A. (2011). The effect of relationship status on communicating emotions through touch. *Cognition and Emotion*, *25*(2), 295-306.

Thornbury, J. M., & Mistretta, C. M. (1981). Tactile sensitivity as a function of age. *Journal of gerontology*, *36*(1), 34-39.

Tieri, G., Tidoni, E., Pavone, E. F., & Aglioti, S. M. (2015). Body visual discontinuity affects feeling of ownership and skin conductance responses. *Scientific reports, 5*(1), 17139.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B. J., & Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry research, 168*(3), 242-249.

Triscoli, C., Ackerley, R., & Sailer, U. (2014). Touch satiety: differential effects of stroking velocity on liking and wanting touch over repetitions. *PLoS One, 9*(11), e113425.

Triscoli, C., Croy, I., Olausson, H., & Sailer, U. (2017). Touch between romantic partners: Being stroked is more pleasant than stroking and decelerates heart rate. *Physiology & behavior, 177,* 169-175.

Triscoli, C., Croy, I., Steudte-Schmiedgen, S., Olausson, H., & Sailer, U. (2017). Heart rate variability is enhanced by long-lasting pleasant touch at CT-optimized velocity. *Biological psychology, 128,* 71-81.

Trotter, P., McGlone, F., Reniers, R., & Deakin, J. (2018). Construction and validation of the touch experiences and attitudes questionnaire (TEAQ): a self-report measure to determine attitudes toward and experiences of positive touch. *Journal of Nonverbal Behavior, 42*(4), 379-416.

Uchino, B. N. (2006). Social support and health: a review of physiological processes potentially underlying links to disease outcomes. *Journal of Behavioral Medicine, 29*, 377-387.

Ulrich-Lai, Y. M., & Herman, J. P. (2009). Neural regulation of endocrine and autonomic stress responses. *Nature reviews neuroscience, 10*(6), 397-409.

Upenieks, L., & Schafer, M. H. (2022). Keeping “in touch”: Demographic patterns of interpersonal touch in later life. *Research on Aging, 44*(1), 22-33.

Uusberg, A., Thiruchselvam, R., & Gross, J. J. (2014). Using distraction to regulate emotion: Insights from EEG theta dynamics. *International journal of Psychophysiology, 91*(3), 254-260.

Uvnäs-Moberg, K. (1998). Oxytocin may mediate the benefits of positive social interaction and emotions. Psychoneuroendocrinology, Vachon-Presseau, E., Roy, M., Martel, M.-O., Albouy, G., Chen, J., Budell, L., Sullivan, M. J., Jackson, P. L., & Rainville, P. (2012). Neural processing of sensory and emotional-communicative information associated with the perception of vicarious pain. *Neuroimage, 63*(1), 54-62.

Vallbo, Å., Olausson, H., & Wessberg, J. (1999). Unmyelinated afferents constitute a second system coding tactile stimuli of the human hairy skin. *Journal of neurophysiology, 81*(6), 2753-2763.

Van de Mortel, T. F. (2008). Faking it: social desirability response bias in self-report research. *Australian Journal of Advanced Nursing, The, 25*(4), 40-48.

van Raalte, L. J., & Floyd, K. (2021). Daily hugging predicts lower levels of two proinflammatory cytokines. *Western Journal of Communication, 85*(4), 487-506.

Verney, S. P., Granholm, E., & Marshall, S. P. (2004). Pupillary responses on the visual backward masking task reflect general cognitive ability. *International journal of Psychophysiology, 52*(1), 23-36.

Victor, C. R. (2021). The languages of loneliness: developing a vocabulary for researching social health. *Loneliness and the built environment. Datutop Occasional Papers, 40,* 51-71.

Victor, C. R., Scambler, S. J., Shah, S., Cook, D. G., Harris, T., Rink, E., & De Wilde, S. (2002). Has loneliness amongst older people increased? An investigation into variations between cohorts. *Ageing & Society, 22*(5), 585-597.

Victor, C. R., & Yang, K. (2012). The prevalence of loneliness among adults: a case study of the United Kingdom. *The Journal of psychology, 146*(1-2), 85-104.

Viola, P., & Jones, M. (2001, 8-14 Dec. 2001). Rapid object detection using a boosted cascade of simple features. Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. CVPR 2001,

von Mohr, M., Crowley, M. J., Walthall, J., Mayes, L. C., Pelphrey, K. A., & Rutherford, H. J. (2018a). EEG captures affective touch: CT-optimal touch and neural oscillations. *Cognitive, Affective, & Behavioral Neuroscience, 18*, 155-166.

von Mohr, M., Crowley, M. J., Walthall, J., Mayes, L. C., Pelphrey, K. A., & Rutherford, H. J. (2018b). EEG captures affective touch: CT-optimal touch and neural oscillations. *Cognitive, Affective, & Behavioral Neuroscience, 18*(1), 155-166.

Von Mohr, M., & Fotopoulou, A. (2018). of interoception: Active and social inference of pain and pleasure on. *The interoceptive mind: From homeostasis to awareness, 102*.

von Mohr, M., Kirsch, L. P., & Fotopoulou, A. (2017). The soothing function of touch: affective touch reduces feelings of social exclusion. *Scientific reports, 7*(1), 1-9.

Von Mohr, M., Kirsch, L. P., & Fotopoulou, A. (2021a). Social touch deprivation during COVID-19: effects on psychological wellbeing and craving interpersonal touch. *Royal Society open science, 8*(9), 210287.

Von Mohr, M., Kirsch, L. P., & Fotopoulou, A. (2021b). Social touch deprivation during COVID-19: effects on psychological wellbeing, tolerating isolation and craving interpersonal touch.

Voos, A. C., Pelphrey, K. A., & Kaiser, M. D. (2013). Autistic traits are associated with diminished neural response to affective touch. *Social cognitive and affective neuroscience, 8*(4), 378-386.

Vrana, S. R., & Rollock, D. (1998). Physiological response to a minimal social encounter: Effects of gender, ethnicity, and social context. *Psychophysiology, 35*(4), 462-469.

Vrijkotte, T. G., Van Doornen, L. J., & De Geus, E. J. (2000). Effects of work stress on ambulatory blood pressure, heart rate, and heart rate variability. *Hypertension, 35*(4), 880-886.

Waldstein, S. R., Bachen, E. A., & Manuck, S. B. (1997). Active coping and cardiovascular reactivity: a multiplicity of influences. *Psychosomatic Medicine, 59*(6), 620-625.

Walker, S., & McGlone, F. (2013). The social brain: neurobiological basis of affiliative behaviours and psychological well-being. *Neuropeptides, 47*(6), 379-393.

Walker, S. C., Trotter, P. D., Woods, A., & McGlone, F. (2017). Vicarious ratings of social touch reflect the anatomical distribution & velocity tuning of C-tactile afferents: A hedonic homunculus? *Behavioural brain research, 320,* 91-96.

Wang, C.-A., Baird, T., Huang, J., Coutinho, J. D., Brien, D. C., & Munoz, D. P. (2018). Arousal effects on pupil size, heart rate, and skin conductance in an emotional face task. *Frontiers in neurology, 9,* 1029.

Wang, F., Gao, Y., Han, Z., Yu, Y., Long, Z., Jiang, X., Wu, Y., Pei, B., Cao, Y., & Ye, J. (2023). A systematic review and meta-analysis of 90 cohort studies of social isolation, loneliness and mortality. *Nature Human Behaviour*, 1-13.

Wang, H.-M., & Huang, S.-C. (2012). SDNN/RMSSD as a surrogate for LF/HF: a revised investigation. *Modelling and Simulation in Engineering, 2012*(1), 931943.

Watt, J. A., Goodarzi, Z., Veroniki, A. A., Nincic, V., Khan, P. A., Ghassemi, M., Lai, Y., Treister, V., Thompson, Y., & Schneider, R. (2021). Comparative efficacy of interventions for reducing symptoms of depression in people with dementia: systematic review and network meta-analysis. *bmj, 372*.

Watt, J. A., Goodarzi, Z., Veroniki, A. A., Nincic, V., Khan, P. A., Ghassemi, M., Thompson, Y., Tricco, A. C., & Straus, S. E. (2019). Comparative efficacy of interventions for aggressive and agitated behaviors in dementia: a systematic review and network meta-analysis. *Annals of internal medicine, 171*(9), 633-642.

Wessberg, J., & Norrsell, U. (1993). A system of unmyelinated afferents for innocuous mechanoreception in the human skin. *Brain research, 628*(1-2), 301-304.

Weze, C., Leathard, H. L., Grange, J., Tiplady, P., & Stevens, G. (2007). Healing by Gentle Touch Ameliorates Stress and Other Symptoms in People Suffering with Mental Health Disorders or Psychological Stress. *Evidence-Based Complementary and Alternative Medicine, 4*(1), 697459. https://doi.org/https://doi.org/10.1093/ecam/nel052

Wheldall, K., Bevan, K., & Shortall, K. (1986). A touch of reinforcement: the effects of contingent teacher touch on the classroom behaviour of young children. *Educational Review, 38*(3), 207-216.

White, I. R., Royston, P., & Wood, A. M. (2011). Multiple imputation using chained equations: issues and guidance for practice. *Statistics in medicine, 30*(4), 377-399.

Whitmarsh, S., Nieuwenhuis, I. L., Barendregt, H. P., & Jensen, O. (2011). Sensorimotor alpha activity is modulated in response to the observation of pain in others. *Frontiers in human neuroscience, 5*, 91.

Wilhelm, F. H., Kochar, A. S., Roth, W. T., & Gross, J. J. (2001). Social anxiety and response to touch: incongruence between self-evaluative and physiological reactions. *Biological psychology, 58*(3), 181-202.

Xu, S., Xu, C., & Gerling, G. J. (2023). Social and Emotional Touch Between Romantic Partners is Affectively More Pleasant Due to Finely Tuned Contact Interactions. *IEEE Transactions on Haptics*.

Yamanaka, K., & Kawakami, M. (2009). Convenient evaluation of mental stress with pupil diameter. *International journal of occupational safety and ergonomics, 15*(4), 447-450.

Yanagisawa, H., Dan, I., Tsuzuki, D., Kato, M., Okamoto, M., Kyutoku, Y., & Soya, H. (2010). Acute moderate exercise elicits increased dorsolateral prefrontal activation and improves cognitive performance with Stroop test. *Neuroimage, 50*(4), 1702-1710.

Yang, C.-Y., Decety, J., Lee, S., Chen, C., & Cheng, Y. (2009). Gender differences in the mu rhythm during empathy for pain: an electroencephalographic study. *Brain research, 1251*, 176-184.

Yoshida, S., Kawahara, Y., Sasatani, T., Kiyono, K., Kobayashi, Y., & Funato, H. (2020). Infants show physiological responses specific to parental hugs. *Iscience, 23*(4).

Yu, X., Fumoto, M., Nakatani, Y., Sekiyama, T., Kikuchi, H., Seki, Y., Sato-Suzuki, I., & Arita, H. (2011). Activation of the anterior prefrontal cortex and serotonergic system is associated with improvements in mood and EEG changes induced by Zen meditation practice in novices. *International journal of Psychophysiology, 80*(2), 103-111.

Zhai, J., & Barreto, A. (2008). Stress detection in computer users through non-invasive monitoring of physiological signals. *Blood, 5*(0).

Zhang, Y., Li, S., Wang, J., Wang, P., Tu, Y., Li, X., & Wang, B. (2019). Pupil size estimation based on spatially weighted corneal flux density. *IEEE Photonics Journal, 11*(6), 1-9.

Zingaretti, P., Petta, A. M., Cruciani, G., & Spitoni, G. F. (2019). Tactile sensitivity, tactile acuity, and affective touch: from childhood to early adolescence. *Somatosensory & motor research, 36*(1), 90-96.

Appendices

Appendix A: Chapter 2 – Interpersonal Touch and the Importance of Romantic Partners for Older Adults' Neuroendocrine Health

Table A.1. *Descriptive statistics of respondents in the analytic sample versus those not in the analytic sample by sociodemographic characteristics and covariates*

Sociodemographic characteristics and covariates	Present in analytic sample (n=1,419)	Not present in analytic sample (n=1,586)
	Frequency (%)	**Frequency (%)**
Sex		
Men	**51.02**	**46.03**
Women	**48.98**	**53.97**
Age		
57-64	**32.49**	**35.25**
65-74	**38.34**	**34.55**
75-85	**29.18**	**30.20**
Educational Attainment		
< High school degree	**22.20**	**24.21**
High school degree or equivalent	**26.71**	**26.10**
Some college or associate degree	**28.19**	**28.75**
Bachelor's degree or higher	**22.90**	**20.93**
Total Household Assets		
0-49,999	**20.50**	**24.13**
50,000-99,999	**11.86**	**8.74**
100,000-499,999	**39.20**	**37.18**
500k or higher	**28.44**	**29.95**

Ethnicity		
White	**74.58**	**70.03**
Non-White	**25.42**	**29.97**
Romantic Partner		
Yes	**66.53**	**67.40**
No	**33.47**	**32.60**
Number of co-residents		
Lives alone	**27.05**	**28.90**
Lives with one other person	**51.98**	**49.84**
Lives with two or more persons	**20.97**	**21.26**
Frequency of Sexual Touch		
No sex	**50.73**	**50.82**
Infrequent sexual touch	**10.45**	**12.11**
Frequent sexual touch	**38.82**	**37.07**
Alcohol Intake		
Regular drinkers	**54.86**	**48.97**
Non-regular drinkers	**24.71**	**26.12**
Never drank alcohol	**20.43**	**24.91**
Frequency of Touch with Partner		
>Weekly	**76.99**	**76.38**
Weekly	**9.45**	**12.07**
Monthly	**5.69**	**4.60**
Yearly or less	**7.86**	**6.95**
Frequency of Touch with Others		
>Weekly	**20.02**	**22.12**
Weekly	**21.31**	**19.30**

Monthly	**12.61**	**11.99**
Yearly or less	**46.07**	**46.59**

Note. All those not in the analytic sample had missing values for at least one of the eight biomarkers used as outcome variables.

Figure A.1. *Scree plot showing the eigenvalues for each individual component.*

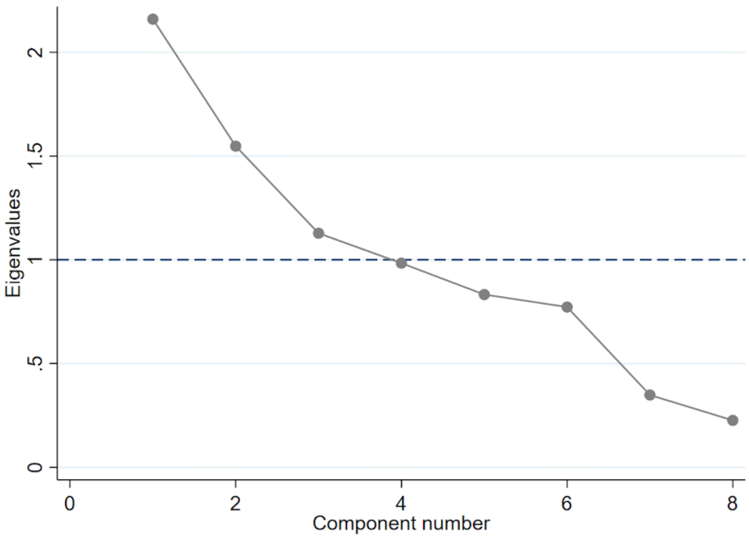
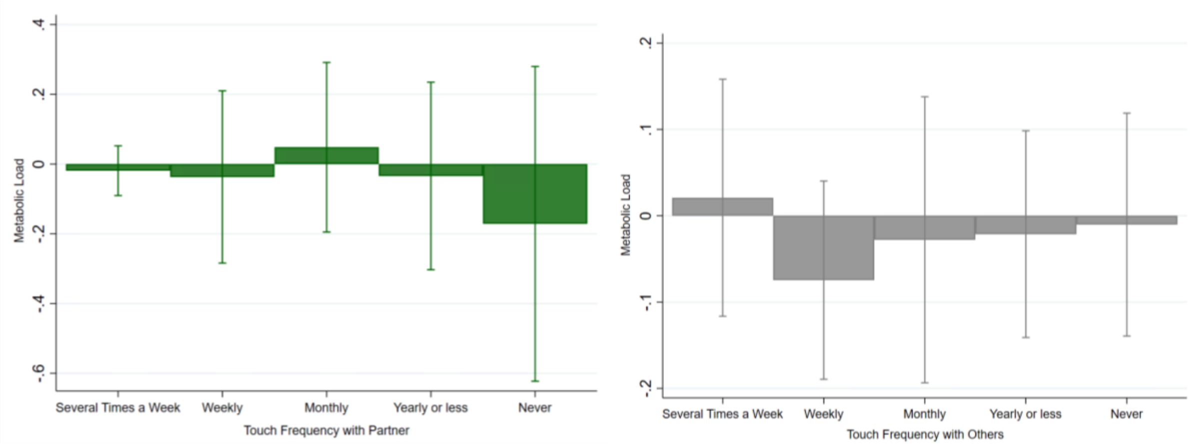


Table A.2. *Weighted component loadings for each biomarker for the full sample.*

Biomarker	**Metabolic Health**	**Cardiovascular Health**	**Neuroendocrine Health**
BMI (kg/m^2)	0.89	0.13	-0.16
Waist Circumference (inches)	0.89	0.12	-0.20
CRP (log transformed) (mg/L)	0.49	-0.02	0.34
HBa1C (percent of total haemoglobin)	0.47	-0.17	0.14
Systolic Blood Pressure (mm Hg)	0.01	0.88	-0.07

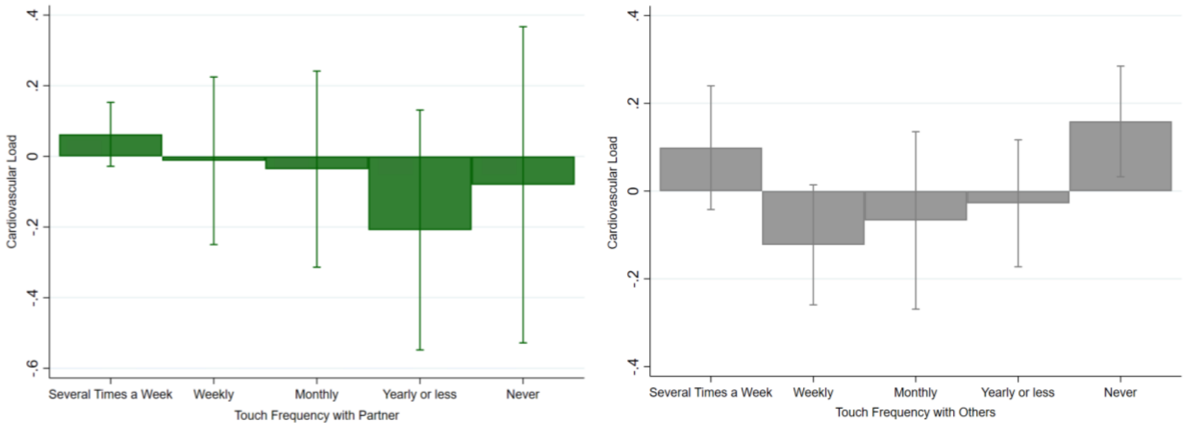
Diastolic Blood Pressure (mm Hg)	0.06	0.87	0.22
Pulse (beats/min)	0.08	-0.04	0.82
DHEA (pg/mL)	0.09	-0.09	-0.49

Figure A.2. *No association of metabolic health and partner touch frequency (left) and other close adult touch frequency (right)*



Note. More positive metabolic load scores indicate worse metabolic health. Lines represent 95% confidence intervals.

Figure A.3. *No association of cardiovascular health and partner touch frequency (left) and other close adult touch frequency (right)*



Note. More positive cardiovascular load scores indicates worse cardiovascular health. Lines represent 95% confidence intervals.

Appendix B: Chapter 3 - The Longitudinal associations between Romantic Touch and Metabolic and Cardiovascular Health in Older Adults

Table B.1. *Descriptive statistics of respondents in the analytic sample versus those not in the analytic sample by sociodemographic characteristics and covariates*

Sociodemographic characteristics and covariates	Present in analytic sample (n=787)	Not present in analytic sample (n=1,474)
	Frequency (%)	**Frequency (%)**
Sex		
Men	**51.70**	**45.90**
Women	**48.30**	**54.10**
Age		
Wave 1		
57-64	**37.10**	**38.30**
65-74	**40.20**	**36.10**
75-85	**22.70**	**25.60**
Wave 2		
62-69	**36.20**	**37.90**
70-79	**40.80**	**36.20**
80-91	**23.00**	**26.00**
Educational Attainment*		
< High school degree	**18.30**	**21.20**
High school degree or equivalent	**24.10**	**25.60**
Some college or associate degree	**32.10**	**29.60**
Bachelor’s degree or higher	**25.40**	**23.60**

Total Household Assets*[a]		
0-49,999	**16.00**	**17.80**
50,000-99,999	**9.15**	**6.72**
100,000-499,999	**33.50**	**29.20**
500k or higher	**26.00**	**22.30**
Ethnicity*[b]		
White	**73.10**	**69.10**
Non-White	**24.40**	**28.20**
Romantic Partner*		
Yes	**70.30**	**71.50**
No	**29.70**	**28.50**
Number of co-residents*		
Lives alone	**24.90**	**25.30**
Lives with one other person	**54.10**	**53.90**
Lives with two or more persons	**21.00**	**20.80**
Frequency of Sexual Touch *[c]		
No sex	**43.60**	**45.30**
Infrequent sexual touch	**11.70**	**11.90**
Frequent sexual touch	**42.90**	**39.60**
Alcohol Intake*[d]		
Regular drinkers	**43.60**	**40.80**
Non-regular drinkers	**23.50**	**22.00**
Never drank alcohol	**16.30**	**20.80**
Frequency of Touch with Partner		
Wave 1[e]		
>Weekly	**51.80**	**51.50**

Weekly	**5.97**	**7.80**
Monthly	**7.50**	**5.83**
Never	**1.02**	**1.15**
Wave 2[f]		
>Weekly	**39.40**	**34.90**
Weekly	**5.08**	**5.90**
Monthly	**5.97**	**6.17**
Never	**2.80**	**2.78**
Frequency of Touch with Others		
Wave 1[g]		
>Weekly	**20.10**	**21.30**
Weekly	**21.10**	**18.50**
Monthly	**28.30**	**28.30**
Never	**24.30**	**24.90**
Wave 2[h]		
>Weekly	**42.90**	**40.60**
Weekly	**20.10**	**19.00**
Monthly	**19.10**	**18.20**
Never	**6.23**	**5.43**

Note. *Responses were used from Wave 1 and if not available, from Wave 2

[a] 120 (15.20%) respondents in the analytic sample and 354 (24.00%) in the non-analytic sample had incomplete responses for total household assets

[b] 20 (2.54%) respondents in the analytic sample and 41 (2.78%) in the non-analytic sample had incomplete responses for ethnicity

[c] 14 (1.78%) respondents in the analytic sample and 48 (3.26%) in the non-analytic sample had incomplete responses for frequency of sexual touch

[d] 131 (16.60%) respondents in the analytic sample and 240 (16.30%) in the non-analytic sample had incomplete responses for alcohol intake

[e] 265 (33.70%) respondents in the analytic sample and 497 (33.70%) in the non-analytic sample had incomplete responses for frequency of touch with a romantic partner at Wave 1

[f] 368 (46.8%) respondents in the analytic sample and 741 (50.30%) in the non-analytic sample had incomplete responses for frequency of touch with a romantic partner at Wave 2

[g] 49 (6.23%) respondents in the analytic sample and 103 (6.99%) in the non-analytic sample had incomplete responses for frequency of touch with other close adults at Wave 1

[h] 92 (11.70%) respondents in the analytic sample and 247 (16.80%) in the non-analytic sample had incomplete responses for frequency of touch with other close adults at Wave 2

Appendix C: Chapter 5 - Electrophysiological Correlates of Touch in Older Adults: EEG and ECG Responses to Close, Stranger, and Vicarious Interactions

Table C.1. Differences between theta, beta, and alpha spectral power during sitting rest and standing rest across prefrontal, frontal, central, parietal, temporal, and occipital scalp regions.

	Prefrontal	Frontal	Central	Parietal	Temporal	Occipital
Theta						

Sit vs. stand	-.13 (.14)	-.17 (.07)*	-.04 (.22)	-.04 (.21)	-.11 (.32)*	-.07 (.28)
Beta						
Sit vs. stand	-.09 (.06)	-.18 (.06)**	.03 (.04)	.01 (.03)	-.04 (.05)	-.08 (.04)
Alpha						
Sit vs. stand	-.13 (.08)	-.17 (.04)**	-.03 (.03)	-.09 (.04)*	-.09 (.02)**	-.17 (.05)**

Note. Differences are presented as mean difference (standard error). The difference scores represent sit rest minus stand rest. *p < .05, **p < .01 corrected values.

Table C.2. Post hoc pairwise comparisons with Bonferroni correction on pleasantness ratings between touch-type conditions (stroking, hugging, handshakes, and rest) for touch shared with close individuals, strangers, and vicarious

	Pleasantness (mean difference (SE))
Vicarious stroking vs. vicarious hugging	-1.51 (.25)**
Vicarious stroking vs. vicarious handshakes	0.23 (.25)
Vicarious stroking vs. close stroking	-1.26 (.24)**
Vicarious stroking vs. close hugging	-2.40 (.29)**
Vicarious stroking vs. close handshakes	-0.55 (.29)
Vicarious stroking vs. stranger stroking	-0.81 (.24)*
Vicarious stroking vs. stranger hugging	-1.26 (.29)**
Vicarious stroking vs. stranger handshakes	-0.72 (.29)
Vicarious hugging vs. vicarious handshakes	1.74 (.25)**
Vicarious hugging vs. close stroking	0.26 (.29)
Vicarious hugging vs. close hugging	-0.89 (.24)*
Vicarious hugging vs. close handshakes	0.96 (.29)*

Vicarious hugging vs. stranger stroking	0.70 (.29)
Vicarious hugging vs. stranger hugging	0.26 (.24)
Vicarious hugging vs. stranger handshakes	0.79 (.29)
Vicarious handshakes vs. close stroking	-1.49 (.29)**
Vicarious handshakes vs. close hugging	-2.64 (.29)**
Vicarious handshakes vs. close handshakes	-0.79 (.24)
Vicarious handshakes vs. stranger stroking	-1.04 (.29)*
Vicarious handshakes vs. stranger hugging	-1.49 (.29)**
Vicarious handshakes vs. stranger handshakes	-0.96 (.24)**
Close stroking vs. close hugging	-1.15 (.25)**
Close stroking vs. close handshakes	0.70 (.25)
Close stroking vs. stranger stroking	0.45 (.24)
Close stroking vs. stranger hugging	0.00 (.29)
Close stroking vs. stranger handshakes	0.53 (.29)
Close hugging vs. close handshakes	1.85 (.25)**
Close hugging vs. stranger stroking	1.60 (.29)**
Close hugging vs. stranger hugging	1.15 (.24)**
Close hugging vs. stranger handshakes	1.68 (.29)**
Close handshakes vs. stranger stroking	-0.26 (.29)
Close handshakes vs. stranger hugging	-0.70 (.29)
Close handshakes vs. stranger handshakes	-0.17 (.24)
Stranger stroking vs. stranger hugging	-0.45 (.25)
Stranger stroking vs. stranger handshakes	0.09 (.25)
Stranger hugging vs. stranger handshakes	0.53 (.25)

3. *Note.* Data are presented as mean difference (standard error) of the first mentioned condition minus the second mentioned conditions (e.g., vicarious stroking – vicarious hugging). **p* < .05, ***p* < .01 corrected values.