MASTERARBEIT | MASTER'S THESIS

Titel | Title

The Power of Touch
The Role of Attachment Style in the Experience and Physiological Impact of Classical Massage

verfasst von | submitted by

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angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2026

Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 066 827
Studienrichtung lt. Studienblatt | Degree programme as it appears on the student record sheet:	Masterstudium Evolutionäre Anthropologie
Betreut von | Supervisor:	Mag. Dr. Sabine Tebbich Privatdoz.
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English Abstract

From primate grooming to a reassuring hand on the shoulder, touch has shaped social life long before language emerged, yet how individuals with different relational histories respond to structured touch interventions remains poorly understood. The present within-subject crossover study examined whether avoidant and anxious attachment style, assessed continuously via the ECR-RD, moderated the effects of a standardized 25-minute classical massage on affect, physiological stress and pain tolerance in a non-clinical sample of adult women. Fifty female participants (M = 25.0 years, SD = 2.8) completed both a massage and a conversation-based control session on consecutive days, with condition order counterbalanced. Outcome measures involved, current affect via the German PANAS, acute stress operationalized as Moments of Stress from wrist-based electrodermal activity recordings using the Empatica E4 and pain tolerance via pressure algometry and wall-sit endurance. None of the three primary hypotheses received statistical support. At the level of post-intervention scores, however, higher avoidant attachment was significantly associated with elevated negative affect across both conditions, a pattern more consistent with a trait-level negativity bias than with intervention-specific reactivity. Massage produced a large, attachment-independent reduction in Moments of Stress relative to the control condition (V = 376, p = .003, r = .54), suggesting that the parasympathetic effects of classical massage operate through bottom-up somatosensory pathways robust to individual differences in relational history. Findings are discussed with reference to a two-pathway model distinguishing CT-afferent-mediated stress regulation from mu-opioid-dependent affective processing.

Abstract Deutsch

Von der Fellpflege bei Primaten bis zur beruhigenden Hand auf der Schulter ist Berührung eine der ältesten Formen menschlicher Verbindung, und dennoch ist wenig darüber bekannt, ob ihre regulatorischen Effekte für alle Menschen gleichermaßen gelten. Die vorliegende Within-Subject-Crossover-Studie untersuchte, ob vermeidender und ängstlicher Bindungsstil, kontinuierlich erfasst mit dem ECR-RD, die Wirkung einer standardisierten 25-minütigen klassischen Massage auf Schmerztoleranz, affektiven Zustand und physiologischen Stress in einer nicht-klinischen Stichprobe erwachsener Frauen moderiert. Fünfzig weibliche Probandinnen (M = 25,0 Jahre, SD = 2,8) absolvierten an zwei aufeinanderfolgenden Tagen sowohl eine Massagebedingung als auch eine gesprächsbasierte Kontrollsession mit ausbalancierter Reihenfolge. Die Outcome-Maße umfassten, aktuellen affektiven Zustand mittels der deutschsprachigen PANAS, sowie akuten physiologischen Stress, operationalisiert als algorithmisch detektierte Stressmomente aus handgelenkbasierten EDA-Aufzeichnungen über das Empatica E4 und Schmerztoleranz mittels Druckalgometrie und Wandsitztest. Keine der drei primären Hypothesen wurde statistische unterstützt. Auf Ebene der Post-Interventionswerte war höherer vermeidender Bindungsstil jedoch signifikant mit erhöhtem negativem Affekt assoziiert, ein Muster, das konsistenter mit einer trait-spezifischen Negativitätstendenz als mit interventionsspezifischer Reaktivität erscheint. Massage führte zu einer großen, bindungsstil-unabhängigen Reduktion der Stressmomente (V = 376, p = .003, r = ,54), was darauf hindeutet, dass die parasympathischen Regulationseffekte klassischer Massage über bottom-up somatosensorische Pfade wirken, die gegenüber individuellen Unterschieden in der Bindungsgeschichte robust sind. Die Befunde werden anhand eines Zwei-Pfad-Modells diskutiert.

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List of Abbreviations

ACC: Anterior Cingulate Cortex

BANG: Bindungsangst (Anxious Attachment Subscale, ECR-RD)

BOTSA: Brain Opioid Theory of Social Attachment

BRMS: Bech-Rafaelsen Melancholia Scale

BVER: Bindungsvermeidung (Avoidant Attachment Subscale, ECR-RD)

CI: Confidence Interval

CT: C-Tactile (Afferents)

C-LTMR: C Low-Threshold Mechanoreceptor

ECR-RD: Experiences in Close Relationships Revised, German Version

EDA: Electrodermal Activity

fMRI: Functional Magnetic Resonance Imaging

GSR: Galvanic Skin Response

H1 / H2 / H3: Hypothesis 1 / Hypothesis 2 / Hypothesis 3

HAMD: Hamilton Depression Scale

HARS: Hamilton Anxiety Rating Scale

HPA: Hypothalamic-Pituitary-Adrenal (Axis)

HRV: Heart Rate Variability

ICU: Intensive Care Unit

LEP: Laser-Evoked Potentials

M: Mean

MASSAG: Multisystem Affective and Somatosensory Stress Attenuation through Graded manipulations (Model)

Mdn: Median

MOR: Mu-Opioid Receptor

MOS: Moments of Stress

OR: Odds Ratio

PA: Positive Affect

PANAS: Positive and Negative Affect Schedule

NA: Negative Affect

PCA: Principal Component Analysis

POMS: Profile of Mood States

PPT: Pressure Pain Threshold

QIDS-SR: Quick Inventory of Depressive Symptomatology, Self-Report

r: Effect Size (Correlation Coefficient)

RCT: Randomized Controlled Trial

SCL: Skin Conductance Level

SCR: Skin Conductance Response

SD: Standard Deviation

SMD: Standardized Mean Difference

STAI: State-Trait Anxiety Inventory

V: Wilcoxon Test Statistic

VAS: Visual Analogue Scale

vmPFC: Ventromedial Prefrontal Cortex

WKO: Wirtschaftskammer Österreich (Austrian Economic Chamber)

1 Introduction

1.1 Why is touch important?

Modern humans are social beings, we evolved under selective pressure to survive through connection via communication, cooperation and physical contact, also known as “touch”. Paradoxically, in our contemporary urban life, a BBC study on touch revealed that 54% of respondents experienced too little touch in their daily lives while only 3% had too much of it (Banissy & Hammond, 2020). The relevance of this deficit became particularly apparent during the COVID-19 pandemic, when restricted social contact was associated with measurable increases in anxiety and loneliness (Von Au et al., 2025). To situate this contemporary deficit within a broader explanatory framework, it is necessary to examine the evolutionary and biological origins of the human need for touch.

1.1.1 Evolutionary Foundation: Allogrooming - Hidden Social Dimensions

Although it is tempting to attribute allogrooming solely to its primary, evolutionarily conserved function of hygiene maintenance, specifically the removal of ectoparasites such as ticks, lice, and fleas from body regions inaccessible through self-grooming (Pérez Pérez & Veà, 2000), comparative evidence suggests this explanation is insufficient on its own. Grooming rates across populations correlate with ectoparasite load, and experimental reduction of ectoparasite levels in meerkat (Suricata suricatta) groups caused allogrooming rates to fall by 64%, supporting a genuine hygienic function (Madden & Clutton-Brock, 2009). However, the time investment observed in highly social species far exceeds what parasite removal alone would require (Dunbar, 1991, 2010). Woodhoopoes dedicate only 1% of their leisure time to allopreening, whereas geladas spend up to 17% grooming one another (Dunbar, 2010). This disparity indicates that allogrooming has acquired a derived social function beyond its hygienic origins: It serves not only to establish and maintain affiliative bonds, but also to regulate intra-group conflict, buffer physiological stress, and sustain the cooperative structure of group living (Dunbar, 2010; Madden & Clutton-Brock, 2009).

1.1.2 Tension Reduction Hypothesis

Experimental work by Boccia et al., (1989) monitored multiple physiological parameters in pigtail macaques to test the tension-reduction-hypothesis, proposing that social rather than hygienic aspects of grooming produce innate effects. Analysis of grooming motions revealed that gentle stroking is associated with a decrease in heart rate, following a tension reduction, whereas picking is not. Similar patterns of low heart rates have been observed in grooming recipients during sleeping states (Boccia et al., 1989), as well as in rhesus macaques (Aureli et al., 1999), supporting the tension-reduction effect of grooming.

1.1.3 Bond Stabilization and Endorphin Release

Schino et al. (1988) tested the tension-reduction hypothesis directly by pairing unfamiliar long-tailed macaques and measuring displacement activities as behavioural indicators of tension. Female allogrooming significantly reduced male displacement activities both during and after grooming sessions, suggesting that social touch actively regulates tension within dyads. This is consistent with earlier proposals by de Waal (1984) that allogrooming serves as a primary mechanism for social bonding and affiliate bond formation among primates. The physiological basis for this social function was examined by Keverne et al. (1989), who reunited talapoin monkeys after a period of isolation under three conditions: administration of naltrexone, an opioid receptor antagonist that inhibits endogenous endorphin activity, a very low dose of morphine, or no pharmacological intervention as a baseline condition. Grooming frequency and offers were highest in the naltrexone condition and lowest in the morphine condition, suggesting that endorphin blockage increased grooming seeking, while exogenous opioids reduced it (Keverne et al., 1989). Collectively, these studies indicate that allogrooming engages behavioural and physiological systems well beyond simple hygiene, operating through tension reduction, endorphin release, and heart rate regulation.

1.2 Do the Physiological Benefits of Touch Extend to Humans?

The primate research reviewed above raises a translational question: do the regulatory effects of social touch, established across multiple mammalian species, extend to humans, and if so, through which mechanisms? Addressing this requires examining the peripheral receptor systems through which touch is transduced. These pathways determine not only how touch is subjectively experienced, but also which physiological outcomes structured interventions such as massage can produce.

1.3 How Touch Is Experienced

Touch is not a simple sensation. It is processed through multiple pathways, each activating different neural circuits and producing different effects.

1.3.1 Mechanoreceptors: Pressure Receptors and Continuous Feedback

At the foundation of touch perception are receptors that convert physical contact to neural signals, including mechanoreceptors, pressure receptors and specialized cells such as Meissner corpuscles and Merkel cells. These sensory receptors provide continuous feedback to the central nervous system about pressure, texture and touch location. Stimulation of these receptors can activate parasympathetic activity, producing stress relief, relaxation and well-being (McGlone et al., 2014; Sánchez López de Nava & Raja, 2026).

At the molecular level, PIEZO2 ion channels have been identified as the principal mechanotransducers within cutaneous mechanoreceptors. Rather than relying on a secondary signaling cascade, PIEZO2 responds directly to membrane deformation, converting mechanical skin displacement into an immediate cationic current in dorsal root ganglion neurons (Coste et al., 2010; The Nobel Committee, 2021). Humans carrying loss-of-function mutations in the PIEZO2 gene present with profound deficits in tactile discrimination and proprioception, confirming its essential role in the somatosensory transduction that underlies structured touch interventions such as massage (Chesler et al., 2016).

1.3.2 C tactile Touch, CT – Afferents: Gentle Touch Pathway

Another, more specific pathway involves unmyelinated, slow-conducting nerve fibres called C-tactile afferents, which are found primarily in hairy skin and are activated by gentle, caress-like stroking at velocities of approximately 1 to 10 cm/s, with peak responsiveness around 3 cm/s. CT-afferents are associated with positive affect, increased pain tolerance, and stimulation of the parasympathetic nervous system (Habig et al., 2017; McGlone et al., 2014). In rodent models, these fibers are referred to as C-LTMRs (C low-threshold mechanoreceptors), allowing for comparative interspecies research with similar effects (Huzard et al., 2022). This suggests that these evolved fibers may be specifically dedicated to mediating the calming effects of caress-like touch (Bohic & Abraira, 2022; Gothard & Fuglevand, 2022; Powell et al., 2024).

1.3.3 A-beta Fibres: Discriminative Touch

A third pathway involves fast-conducting myelinated A-beta afferents, which mediate discriminative aspects of touch and allow the nervous system to differentiate between pressure, location, and vibration (McGlone et al., 2014; Olausson et al., 2010).

These fibres are also present in hairy skin but are distinguished from CT-afferents by their sensitivity to pressure rather than velocity: A-beta afferents respond optimally to moderate pressure stimulation, as applied in massage therapy, whereas CT-afferents are tuned to stroking velocity, with peak responsiveness at approximately 3 cm/s (McGlone et al., 2014). However, Case et al. (2023) demonstrated through peripheral nerve block that A-beta afferent input is necessary for the conscious perception of pleasantness during CT-targeted gentle stroking, suggesting that the two pathways operate in concert rather than in isolation.

The distinction between these three pathways directly determines the physiological outcome of touch interventions. Moderate pressure, as applied in classical massage, co-activates mechanoreceptors and A-beta afferents, promoting parasympathetic activation and stress relief (Field, 2019; Triscoli et al., 2017). Light touch alone, by contrast, can unintentionally activate sympathetic arousal, producing the opposite of the intended therapeutic effect (Field, 2019; Triscoli et al., 2017), though the boundary between touch modalities and their respective autonomic outcomes appears more nuanced when interventions are compared directly, a pattern revisited in section 1.5.2 in light of finding by Meier et al. (2020) This mechanistic differentiation bridges primate allogrooming, which similarly involves slow, moderate-pressure stroking over hairy skin, to the clinical effects documented in human massage research.

This mechanistic insight reveals evolutionary continuity: just as primate allogrooming calibrated tension and endorphins through specific stroking patterns, human touch therapies engage the same cellular responses, CT-afferents for affective calm, pressure receptors for physiological regulation, producing measurable behavioural and health outcomes. Touch quality, pressure, and velocity thus emerge not as methodological details but as essential parameters that determine whether an intervention restores equilibrium or disrupts it.

1.3.4 Neural Mechanisms of Touch

The cortical processing of touch further illustrates its deep integration into affective and autonomic regulatory systems. Affective touch engages both bottom-up sensory pathways and top-down modulatory circuits, creating a bidirectional system in which the brain both receives tactile signals and shapes how we experience them (Jinich-Diamant et al., 2026; McGlone et al., 2024).

CT-afferent signals project to the posterior insular cortex, a region associated with interoceptive awareness and the subjective experience of bodily states (Gothard & Fuglevand, 2022; Powell et al., 2024). From here, touch information connects with circuits involved in emotional processing, reward, and social cognition (Elias & Abdus-Saboor, 2022). Beyond the insula, touch engages the anterior cingulate cortex (ACC) and ventromedial prefrontal cortex, structures specifically associated with evaluating social and emotional significance Von Mohr et al. (2018). This neural architecture explains why gentle touch not only feels pleasant but also actively regulates emotional and affective states.

The vagal tone, which reflects parasympathetic activity, is modulated by these pathways and provides a potential link between skin stimulation and autonomic regulation (Elias & Abdus-Saboor, 2022). This bridging of skin and brain operates as a continuous loop: Touch activates peripheral receptors, which signal to cortical regions, which in turn modulate autonomic output and behavioural responses to touch (Elias & Abdus-Saboor, 2022). The system therefore operates as an active, ongoing calibration rather than a passive form of reception, a principle that underpins integrative frameworks of touch-based intervention (Jinich-Diamant et al., 2026).

1.4 Brain Opioid Theory of Social Attachment

The brain opioid theory of social attachment proposes that endogenous opioids, especially β-endorphin acting at mu-opioid receptors (MORs), may encode the rewarding and comforting aspects of social contact and help maintain close bonds over time (Machin & Dunbar, 2011; Pearce et al., 2017). As mentioned before, pharmacological and imaging studies in both non-human primates and humans indicate that grooming and social touch modulate endogenous opioid activity. Blocking opioid receptors (MORs) increases social seeking, whereas stimulating them reduces grooming, consistent with a homeostatic feedback loop (Machin & Dunbar, 2011; Nummenmaa et al., 2016).

In humans, social touch from a close other increases subjective pleasure and alters MOR availability in the thalamus, striatum, insula, cingulate, and frontal cortices, suggesting that touch dynamically engages the same MOR-dependent circuitry that mediates both physical pain relief and social reward (Nummenmaa et al., 2016). When MOR availability, in the form of fewer receptors, is lower in these regions, it is associated with reduced social hedonic capacity and more avoidant attachment in relationships, whereas higher MOR availability is associated with more rewarding social relationships and as discussed in the following section with secure attachment orientations (Nummenmaa et al., 2015; Turtonen et al., 2021).

This attachment-dependent MOR system interacts with CT-mediated affective touch to influence both emotional regulation and pain processing. Slow CT-optimal touch can attenuate early and late pain-related neural responses in individuals with higher attachment anxiety, whereas simultaneous touch may have opposite or blunted effects in those with higher attachment avoidance. This suggests that attachment history tunes how MOR-mediated affective touch is integrated into pain and threat processing (Krahé et al., 2016). Together, these findings support a coherent model in which CT-based social touch, μ-opioid signalling, and attachment style form an integrated loop that calibrates social reward, distress regulation and physiological homeostasis throughout the lifespan (Machin & Dunbar, 2011).

1.5 Universal Effects of Touch Across Conditions

The preceding sections have established the peripheral and central mechanisms through which touch is transduced and processed. The critical empirical question is whether these mechanisms converge on consistent, measurable regulatory outcomes across diverse populations and conditions. The neural mechanisms are well-studied: peripheral receptors signal to insular cortex, limbic regions, and prefrontal circuits that jointly regulate affect, pain, and autonomic tone.

Across conditions as varied as acute pain, chronic stress, mood dysregulation, immune function, and social bonding, touch consistently engages the same fundamental regulatory capacity (Packheiser et al., 2024). Rather than activating isolated circuits, it appears to recalibrate homeostatic balance across multiple physiological and psychological domains simultaneously (Field, 2019; Triscoli et al., 2017), a pattern consistent with an evolutionarily conserved function in which social contact serves as a primary mechanism for maintaining physiological and psychological equilibrium (Dunbar, 2010; Machin & Dunbar, 2011).

Yet, touch research has historically been fragmented, with affective touch, massage therapy, and social neuroscience conducted largely in parallel, a problem noted by researchers in the field. Field (2019), citing a reviewer, captures this tension directly:

> "The differentiation between CT [C-tactile afferent-mediated] touch, social touch and massage is rather confusing and perhaps an arbitrary differentiation... Despite these fields overlapping substantially, they are often researched as distinct entities by distinct research groups. It is highly valuable to combine the knowledge gained from these fields as well as encourage researchers to consider the other research fields when conducting their research..." (p. 140).

This integration, bringing together affective touch, neuroscience, and massage research, reveals that different forms of touch engage the same fundamental psychobiological regulatory systems in humans. When we synthesize evidence across these domains, a unified pattern emerges.

1.5.1 Pain Reduction

Pain reduction represents one of the most robust benefits of touch. CT-optimal slow stroking (≈3 cm/s) outperforms faster velocities (30 cm/s) or vibration in reducing pain perception (Liljencrantz et al., 2017). Meta-analyses support this effect: Crawford et al. (2016) reported a SMD of −1.14 (95% CI −1.94 to −0.35) across massage interventions, while (Farber & Wieland, 2016) found that massage outperformed active controls for chronic low back pain in 25 RCTs (N=3,096; SMD −0.37, 95% CI −0.62 to −0.13), with benefits persisting up to six months.

Even brief touch-based interventions appear to be effective. A 20-minute hand massage reduced postoperative pain intensity, unpleasantness, and anxiety in cardiac surgery ICU patients beyond routine pharmacological management (Boitor et al., 2015, 2018). Ironman triathletes showed significantly lower subjectively perceived pain and fatigue in the quadriceps following a single post-race massage of effleurage, petrissage, and tapotement techniques compared to passive rest, though no significant effect on objective pressure pain thresholds was observed (Nunes et al., 2016). Pain tolerance consistently increases following massage interventions, as assessed via cold pressor test (Knight & Napier, 2020), algometry (Moyer et al., 2011), and wall-sit endurance protocols used in social network research on pain (Johnson & Dunbar, 2016). Depressed patients similarly reported significantly less pain after massage ($p = .003$, $r = .39$; Arnold et al., 2020).

1.5.2 Stress Regulation

Touch affects the autonomic nervous system and HPA-axis activity, further regulating cortisol secretion, subjective stress experience, and heart rate variability. Whether through naturalistic touch (handholding, hugging) or structured interventions (massage, stroking), calming effects emerge in any case.

Cortisol, the primary stress hormone reflecting HPA-axis activity, demonstrates inconsistent responses following touch interventions. While some studies report increases in beta-endorphin alongside subjective relaxation (Sumioka et al., 2013), cortisol reductions following touch interventions are documented particularly in clinical populations with elevated baseline stress (Field et al., 2005), though meta-analytic findings suggest responses vary substantially by intervention context and population type (Qiu et al., 2017), indicating that stress regulation through touch operates via a multi-system mechanism rather than a single hormonal marker.

Heart rate responses seem to reflect measurable stress regulation. Touch is associated with a decreased resting heart rate and increased heart rate variability (Triscoli et al., 2017). These changes shift autonomic balance from sympathetic to parasympathetic tone (Fairhurst et al., 2014; Pawling et al., 2017). CT-optimal touch (3cm/s), specifically linked to parasympathetic pathways, shows significantly lower heart rates compared to non-optimal velocities (30cm/s) with a very high effect size of partial $\eta^2 = 0.27$ (Pawling et al., 2017). Interestingly, CT-fibre sensitivity may be present from infancy, as early as nine months of age. Significantly lower heart rates have been measured in CT-optimal touch compared to non-optimal velocities (30cm/s and 1cm/s) (Fairhurst et al., 2014).

Subjective stress and tension decreased during a 60-minute massage in depressive patients (Arnold et al., 2020). Whereas Meier et al. (2020) detected no significant difference between vagal nerve stimulating specific massage, soft shoulder massage and resting control, participants reacted significantly with a higher heart rate variability 24.67% in the touch conditions vs 13.24% in the non-touch control condition,

Perhaps most striking, even non-human touch was associated with decreased cortisol in participants. While having a conversation with either a mobile phone or a robotic hugging device, cortisol decreased with the hugging device, without significant changes in positive affect (Sumioka et al., 2013). Physiological markers may register the regulatory effects of touch even in the absence of consciously perceived affective change. Ditzen et al. (2007), as reviewed in Ditzen and Heinrichs (2014), found that women showed reduced cortisol and heart rate responses following physical partner contact (neck-shoulder massage), whereas verbal support from the same partner produced no equivalent reduction, suggesting that the stress-regulatory properties of touch are not reducible to the relational support component alone.

On a neurophysiological level, touch modulates emotional processing primarily through alterations in theta band activity, with a specific emphasis on temporal regions. Von Mohr et al. (2018) demonstrated that affective (CT-optimal) stroking, induces a widespread reduction in theta activity across the cortex, ranging from prefrontal to occipital areas. This reduction suggests a distinct neural signature for the soothing, passive reception of social touch. In contrast, spontaneous facial self-touch during acute stress is associated with increased theta activity in the superior frontal and temporal gyri. Grunwald et al. (2014) interpret this upregulation as an active self-regulatory mechanism, helping to manage cognitive and emotional load during stress retention.

Electrodermal activity (EDA) is a key marker of sympathetic arousal, comprising tonic baseline levels (SCL) and phasic responses to stimuli (SCR). While wrist-based recordings yield lower absolute values than palmar sites, they remain directionally consistent and reliably predict affective changes. This sensitivity makes wrist-EDA valuable for capturing physiological regulation during touch interventions, where it has been shown to reflect synchronization and stress (Chatel-Goldman et al., 2014; Van Dooren et al., 2012). Accordingly, these signals provide the physiological basis for the "Moments of Stress" algorithm (Kyriakou et al., 2019), allowing for the objective quantification of stress events during massage.

1.5.3 Depression and Anxiety

Touch indicates to improve how we feel, reducing symptoms of anxiety and depression and promotes subjective feelings of social support and connection. At the subjective level, multiple standardized measures document mood improvements. Depressive mood and somatic symptoms, assessed via the Hamilton Depression Scale (HAMD) and Bech-Rafaelsen Melancholia Scale (BRMS), as well as anxiety assessed via the Hamilton Anxiety Rating Scale (HARS), showed significant improvement after four massage sessions compared to progressive muscle relaxation (Arnold et al., 2020). A systematic review of 17 randomized controlled trials documented effects of massage consistent with moderate antidepressants (fixed and random effects: SMD = 0.76 [95% CI, 0.61–0.91] and 0.73 [95% CI, 0.52–0.93]; heterogeneity: $\tau^2 = 0.06$, Cochran $\chi^2_{16} = 25.77$, $p = .06$) (Hou et al., 2010). In one study, massage was associated with clinically significant anxiety reduction, with massage showing greater reduction than light touch alone. Depression symptoms improved on Depressive Symptomatology (QIDS-SR) (effect size = −0.956, p = 0.03), while STAI-state anxiety showed a trend toward reduction (effect size = −0.675; p = .065) (Rapaport et al., 2016). Crawford et al. 2016) documented improvements in quality of life with anxiety modulation (SMD = −0.57), comparing massage to no treatment (SMD = −1.14), sham controls (SMD = −0.44), and active controls (SMD = −0.26). Even though these meta-analyses support the hypothesis that massage interventions improve anxiety and depression symptoms, massage techniques and other relaxation techniques do not always vary between group differences. Sherman's examination found that therapeutic massage, osteopathic myofascial release, and thermotherapy, relaxing room therapy all produced HARS reductions of 10–13 points without significant between-group differences (Sherman et al., 2010). Classical massage shows less consistent results across studies, with limited support due to small samples (Coelho et al., 2007).

1.5.4 Affect, Mood, Emotional States

Self-report affect and mood questionnaires provide a complementary lens through which touch-induced shifts in emotional state can be assessed. Meier et al. (2020) demonstrated that subjective relaxation increased substantially across all three experimental conditions, including vagus nerve massage, soft shoulder massage, and a resting control group, with a pre-to-post increase from ($t(59) = 8.43$, $p < .001$, Cohen's $d = 1.09$), representing an approximately 50% gain. Notably, this increase did not differ significantly between conditions, suggesting that even brief, structured rest may produce comparable subjective relaxation to active massage. At the item level, more differentiated instruments reveal stronger intervention-specific effects. Rapaport et al. (2016), using the Profile of Mood States (POMS), documented significant reductions in negative affect following Swedish massage compared to light touch, with the largest effect observed for fatigue-inertia (effect size = -0.657, $p = .009$). Together, these findings suggest that massage-induced affective change may be dimension-specific rather than broad, with effects concentrated in subdimensions such as fatigue-inertia that aggregate positive and negative affect scores do not resolve.

This pattern of instrument-sensitivity is further illustrated by Arnold et al. (2020), who assessed affective outcomes using Visual Analogue Scales across depressive symptom-related items. Effects ranged from small to large for negatively valence dimensions, including stress and tension ($r = 0.28$, $p = .03$) and pain sensations ($r = 0.39$, $p = .003$), while positive affect responses showed only weak, non-significant correlations. Similarly, Sumioka et al. (2013) found no significant changes on the PANAS following contact with a huggable robotic device, despite a significant cortisol reduction, further illustrating that physiological regulation and self-reported positive affect do not necessarily co-occur following touch interventions.

1.5.5 Sleep Quality

Touch interventions significantly enhance sleep quality, a fundamental component of stress recovery. Research in critical care settings demonstrated that back massage can effectively counteract sleep disturbances. For instance, Fang et al. 2023) observed a robust increase in subjective sleep quality among ICU patients ($Z = 2.62$, $p = .009$), after receiving a massage therapy. Similarly, brief 10-minute massage sessions over three consecutive nights have been shown to drastically improve sleep scores in ICU patients (from ~546 to ~145, $p < .001$) and significantly reduce poor sleep quality in cardiac patients ($p < .0001$) (Kandeel et al., 2019; Sable et al., 2017).

1.5.6 Immune Function and Health Outcomes

Regular hugging appears associated with reduced infection risk ($OR = 0.39$, $p = 0.04$), the underlying mechanism is thought to be touch buffering against potential immunosuppressive effects of chronic stress. The stress-buffering effect appears to operate such that individuals receiving regular hugs during periods of heightened psychosocial stress experience lower infection risk than those lacking tactile support, suggesting that touch may modulate immune response through HPA-axis and autonomic pathways (Cohen et al., 2015).

1.6 Measuring the Effects of Touch

The present study employed a multimodal measurement battery of pain tolerance, self-reported affect, and objective physiological stress to capture the regulatory effects of massage across behavioural, psychological, and autonomic levels. The following sections describe the instruments and procedures used to operationalize each outcome domain.

1.6.1 Pain Measurement

Pain assessment in touch research spans from subjective self-reports to objective behavioural measures. Pressure pain thresholds are assessed using an algometer (also called dolorimeter), which applies incremental pressure to myofascial tissue sites until the subject reports the sensation transitions from pressure to pain, providing a quantitative measure of pain sensitivity (Moyer et al., 2011). Wall-sit hold duration, the time a subject can maintain an isometric leg position against a wall, serves as a behavioural measure of muscular endurance and discomfort tolerance, frequently used in social network and pain tolerance research (Johnson & Dunbar, 2016)

1.6.2 Measuring Well Being and Adult Attachment

Subjective well-being and affective state are assessed using the Positive and Negative Affect Schedule (PANAS) , a validated 20-item scale distinguishing positive affect (PA: enthusiasm, alertness, ...) from negative affect (NA: distress, guilt, ...)(Watson et al., 1988). In the context of attachment research, PANAS serves as an outcome measure to assess whether attachment style moderates touch-induced changes in affective state; for instance, anxious individuals may show heightened PA during affiliative contact, while avoidant styles correlate with blunted PA/NA differentiation (Bowling et al., 2024; Krahé et al., 2018). Attachment dimensions are measured using the Experiences in Close Relationships-Revised (ECR-R) scale, which quantifies individual differences in attachment avoidance and anxiety across 36 items on continuous scales (Fraley et al., 2000). Combined, PANAS and ECR-R enable investigation of whether attachment style moderates touch-mediated changes in affect.

1.6.3 Measuring Stress E4, Electrodermal Activity and Moments of Stress

The E4 wristband (Empatica) provides continuous, non-invasive recording of heart rate (HR), heart rate variability (HF-HRV), electrodermal activity (EDA), skin temperature. It's validated for autonomic reactivity across conditions including rest, cognitive challenge, physical stress (Menghini et al., 2019; Ollander et al., 2016)

Moments of Stress (MOS) are algorithmically identified using the wrist-based EDA and skin temperature signals from the E4 wristband, following the individual-oriented stress detection algorithm adapted from (Kyriakou et al., 2019). The algorithm identifies periods of heightened sympathetic activity by detecting EDA rise onsets (onset detection) with minimum durations of 1–6 seconds following an electrodermal event, enabling objective identification of stress moments independent of subjective report. This approach enables the objective identification and quantification of stress events independent of subjective report, making it well suited for within-session comparisons in touch intervention research.

1.6.4 Measuring Massage Interventions and Control Conditions

Massage research varies considerably in session duration, applied pressure, stroke technique, and therapist training, all of which influence the magnitude and type of effects observed (Field, 2019; Moyer et al., 2004). Meaningful physiological outcomes such as reductions in cortisol or pain markers are most consistently reported in sessions of 20 to 60 minutes using classical techniques such as effleurage and petrissage (Crawford et al., 2016; Moyer et al., 2004). The choice of control condition differs in how much of the social context they preserve, which in turn determines how cleanly the tactile component can be isolated (Moyer et al., 2004). A structured conversation control holds relational contact constant while removing physical touch, making it particularly appropriate for studies that aim to examine individual-difference moderators of touch-specific effects (Ditzen & Heinrichs, 2014).

1.7 Attachment Style as a Critical Moderator of Touch Response

The regulatory effects of touch do not operate uniformly across individuals. One critical potential moderator is attachment style, the internal working model of relationships that shapes how we seek, experience, and respond to social contact. Individual differences in attachment appear to modify both the affective experience of touch and its neurophysiological effects, operating through the opioid system described in 1.3.2 (Bowling et al., 2024; Chopik et al., 2014).

1.7.1 Pain Modulation and Attachment

Research using laser-evoked potentials (LEP) to measure pain processing via Aδ- and C-nociceptor activation suggests that attachment dimensions may alter both the experience and neural processing of touch-mediated analgesia (Krahé et al., 2016; Von Mohr et al., 2018). Individuals with higher avoidance scores reported less pain when alone compared to when accompanied by an empathetic partner (Krahé et al., 2015). This pattern was reflected in increased N1 and N2 amplitudes on hairy skin, suggesting that avoidant attachment may alter early-stage nociceptive processing in the presence of social support (Krahé et al., 2015, 2016).

1.7.2 Touch and Pleasantness Discrimination Across Attachment Dimensions

Individuals with higher levels of avoidant attachment tend to report fewer positive attitudes toward physical touch and reduced engagement in current intimate touch experiences, indicating a generally more distant stance toward tactile forms of interaction. Bowling et al. (2024) found that attachment dimensions were most strongly associated with attitudes and experiences of intimate touch: those with greater attachment avoidance reported fewer positive attitudes toward intimate touch, while those with greater attachment anxiety reported more positive attitudes. Both attachment avoidance and anxiety predicted reduced likelihood of engaging in current intimate touch experiences.

Importantly, this attitudinal difference does not appear to reflect impaired perceptual discrimination. Krahé et al. (2018) found no strong association between interoception and pleasantness ratings of touch, meaning that avoidant individuals can discriminate pleasant from unpleasant touch just as well as secure or anxious individuals. However, their neurophysiological findings revealed a more complex picture: when pleasant touch was administered to the forearm, higher attachment anxiety predicted attenuated N1 and N2 amplitudes (early and late pain-related components), while higher attachment avoidance predicted opposite results. This suggests that CT-based affective touch may modulate pain processing differently depending on attachment style, with the direction and magnitude of neural responses varying by attachment dimensions.

Supporting these neurophysiological findings, Comte et al. (2024) observed that avoidant participants showed the lowest activation in fMRI scans across all emotions except joy, leading the authors to suggest that self-suppression or inhibition of emotional triggers may be at play. Additionally, research indicates that avoidant individuals tend to show less interest in nonverbal communication and reduced proximity-seeking or display behaviours, which can be understood as a behavioural manifestation of their more distant emotional stance (Takano & Mogi, 2019; Tucker & Anders, 1998).

These findings highlight an important distinction between general attitudes toward touch and specific perceptual abilities. While individuals with avoidant attachment report fewer positive attitudes toward intimate touch and engage in it less frequently, they retain intact discrimination abilities for touch pleasantness (Bowling et al., 2024; Krahé et al., 2018). This suggests that avoidant attachment operates at the level of affective appraisal, cognitive regulation and behavioural motivation and preference rather than sensation or perception. Avoidant individuals appear to evaluate or desire affective touch less positively and to behaviourally avoid proximity and touch, even though their sensory systems and early neural processing remain capable of distinguishing pleasant from unpleasant touch.

1.7.3 Implications for Touch-Based Interventions

These attachment-related differences have important implications for clinical and research practice. Since attachment style modulates both attitudes toward touch and neural pain processing, interventions using massage or affective touch may show variable efficacy depending on participants' attachment profiles. Avoidant individuals may require additional support for touch as clinical rather than interpersonal, or alternative modalities. Anxious individuals may show heightened responsiveness but may also benefit from clarification of intervention boundaries. Understanding attachment as a moderator opens pathways for tailoring touch-based interventions to individual differences in social-emotional processing.

1.8 The Current Study

Despite growing evidence that attachment style shapes responses to touch, it remains unclear whether avoidant attachment influences physiological stress regulation and pain tolerance during massage. This study examines whether attachment style affects responses to classical massage compared to conversation alone.

Given that the sample was exclusively female, menstrual cycle phase and hormonal contraceptive use were documented to allow exploratory assessment of their potential influence on pain-related and affective outcomes. Pain thresholds and tolerance show phase-dependent variation, with some studies reporting reduced pain sensitivity in the follicular and ovulatory phases compared to the late luteal and menstrual phases (Riley et al., 1999), while conditioned pain modulation appears more effective when oestradiol levels are elevated during ovulation (Rezaii et al., 2012). The broader literature remains inconsistent due to heterogeneous methods and stimulus types.

Building on findings that avoidant individuals report less positive touch attitudes toward touch (Bowling et al., 2024), show suppressed neural responses to affective touch (Krahé et al., 2018) and may experience interpersonal proximity as aversive (Comte et al., 2024), the present study examined the moderating role of avoidant attachment across three outcome domains: positive affect, physiological stress, and pain tolerance. The resulting hypotheses are presented in the following section 1.9.

1.9 Research Hypotheses

The study tested three primary hypotheses:

H1: Women with higher avoidant attachment will report lower positive affect (PANAS) following massage than women with non-avoidant attachment.

H2: Women with higher avoidant attachment will experience more Moments of Stress during massage than women with non-avoidant attachment.

H3: Women with higher avoidant attachment will not significantly increase pain tolerance following massage than women with non-avoidant attachment.

Avoidant attachment was identified as the primary dimension of theoretical interest, given its proposed association with suppressed somatosensory reward processing and dampened responsiveness to interpersonal touch (Krahé et al., 2018; Nummenmaa et al., 2015). Anxious attachment was included in all analyses as a comparison dimension to examine the specificity of any observed moderation effects; no directional predictions were formulated for anxious attachment.

2 Methods

2.1 Research Design

This study employed a within-subject experimental design to investigate how a single 25-minute classical massage intervention affects women with different adult attachment styles. The research specifically examined three domains: emotional well-being, physiological stress responses, and pain tolerance. A within-subject approach was selected to enable direct comparison of individual responses across both massage and control conditions, thereby minimizing the impact of between-person variability and increasing statistical power.

Each participant experienced both a massage intervention and a control condition (casual conversation) on two consecutive days with the order randomized to control for potential sequence effects. The experimental procedure was divided into three phases: pre-intervention, during intervention, and post-intervention.

The overall within-subject comparison between the massage and control conversation conditions with respect to emotional well-being, physiological stress responses and pain tolerance was examined as an exploratory analysis, given that the primary hypotheses concerned attachment-moderated effects rather than the main effect of the intervention. Menstrual cycle phase and hormonal contraceptive use were additionally examined as exploratory covariates.

2.2 Participants

2.2.1 Recruitment

Participants were recruited through printed flyers distributed on university campuses and via an online questionnaire administered through SoSciSurvey between November 2023 and January 2024. The online questionnaire was pseudonymized, with each respondent receiving an individual alphanumeric code. Participants could register their interest in the full study by sending an email to the research team after completing the initial screening survey. From 162 individuals who completed the initial questionnaire, 50 women met eligibility criteria and participated in the full experimental study.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Female participants aged 18–40 years
- Willingness to participate in two consecutive experimental sessions
- Ability to provide informed consent

Exclusion criteria:

- Acute inflammatory processes (joints, soft tissues)
- Cardiovascular conditions (heart failure, arteriosclerosis, phlebitis, lymphangitis)
- Current diagnosis of major depressive disorder or acute psychosis
- Dermatological conditions affecting the back (eczema, fungal infections)
- Pregnancy
- Malignant disease

Temporary postponement of participation was permitted for:

- Acute infectious illness (e.g., common cold, influenza)
- Recent injuries to the back or shoulders
- Fever (body temperature > 38°C)

Initial Screening Questionnaire

The recruitment questionnaire assessed demographic characteristics and potential exclusion criteria, including:

- Age
- Pregnancy
- Contraceptive use
- Menstrual cycle phase
- Previous massage experience (coded as: never, 1 time, 2–4 times, 5+ times, regular use)
- Presence of chronic pain or contraindicated medical conditions

2.2.2 Sample Characteristics

The total study cohort comprised 50 female participants (M = 26.1 years, SD = 2.8 years, range: 21–37 years). Each participant completed both experimental conditions across two consecutive sessions, with condition order counterbalanced across participants (25 per order group). Valid sample sizes differed across the three primary hypotheses due to independent sources of data attrition specific to each outcome measure.

For H1 (affective outcomes, PANAS), paired pre- and post-intervention questionnaire data were unavailable for two participants due to incomplete form completion during one of the two sessions, yielding a final paired sample of $n = 48$. The specific reason for the missing paired data in these two cases could not be retrospectively determined.

For H2 (physiological stress, Moments of Stress), only $n = 30$ of the original 50 participants provided usable paired EDA recordings. This substantially higher exclusion rate reflects the technical and methodological demands specific to wrist-based electrodermal activity recording. To ensure that Moments of Stress values reflected genuine sympathetic activation rather than artefactual signal fluctuations, only sessions containing a minimum of 1,000 seconds (16.7 minutes) of valid, artifact-free EDA data in total were retained, irrespective of whether these were recorded continuously or interspersed with brief interruptions. This data quality threshold was established through histogram-based inspection of recording duration distributions and represented the minimum signal length required for reliable algorithmic MOS detection following Kyriakou et al. (2019). Sessions failing to meet this threshold were excluded entirely. Additionally, four participants whose massage condition recordings yielded MOS counts of zero were identified as measurement errors and were excluded from all H2 analyses. In total, 20 participants were removed from the H2 sample, reflecting the cumulative impact of wristband displacement, perspiration-induced signal loss, recording interruptions exceeding 50% of session duration, and the four identified device failures. Because EDA quality could not be fully anticipated or controlled at the point of data collection, as participants varied in skin conductance properties, wrist movement, and wristband fit, these exclusions were determined post-hoc and independently of outcome values.

For H3 (pain tolerance), data from seven participants could not be included because at least one of the two required pain tolerance measurements was missing. The loss arose from two distinct sources: a mid-study transition from the pressure algometer to the wall-sit endurance task following an unplanned device failure. As the within-subject design required complete paired observations per participant, the loss of any single measurement point within a session necessitated exclusion of the entire participant from H3 analyses, resulting in a final paired sample of n = 43.

Attachment dimensions were assessed using the ECR-RD and treated as continuous variables throughout all analyses. Avoidant attachment scores ranged from 1.06 to 4.83 (M = 2.35, SD = 0.98, Mdn = 2.11) and anxious attachment scores from 1.06 to 5.61 (M = 3.04, SD = 1.20, Mdn = 2.89), indicating adequate variance across both dimensions. Both scores fell below general population norms for women (Anxiety: M = 3.56, SD = 1.13; Avoidance: M = 2.92, SD = 1.21; (Fraley, 2012)), consistent with the relatively securely attached profile typical of non-clinical, university-recruited convenience samples(Krahé et al., 2016; Von Mohr et al., 2018). The two attachment dimensions showed a moderate positive intercorrelation ($r = .49$, $p < .001$).

Regarding additional sample characteristics, prior massage experience was limited: the majority of participants (74%) had received fewer than five massages in their lifetime. Menstrual cycle phases at the time of testing were distributed across menstrual (24%), follicular (18%), ovulation (10%), luteal (22%), and irregular patterns (26%); 20% of participants reported current hormonal contraceptive use and were excluded from cycle-phase-based exploratory analyses, as hormonal contraception suppresses endogenous gonadal hormone fluctuations that would otherwise be relevant to affective and physiological outcomes.

2.3 Materials and Devices

2.3.1 Massage Equipment

All massage sessions were conducted using standardized equipment to ensure consistency:

- Massage table: Zen Massage Table "Relax" with adjustable headrest (https://www.massageliegenhaus.com/de/massageliege-zen-relax)
- Massage oil: sunflower seed oil (standard commercial grade), applied uniformly across all participants. The oil was not heated prior to application; however, the therapist warmed the oil between the palms immediately before each application to prevent the sensation of cold contact. Prior to each session, participants were screened for oil allergies or sensitivities; no participant reported adverse reactions.
- Leg support pillow: Positioning pillow placed under the ankles to promote lumbar comfort in prone position.

2.3.2 Questionnaires

Experiences in Close Relationships-Revised (ECR-RD): Adult attachment style was assessed using the German version of the Experiences in Close Relationships-Revised questionnaire (Ehrenthal et al., 2009). The ECR-RD comprises 36 items measuring two continuous dimensions: avoidant attachment (BVER; 18 items) and anxious attachment (BANG; 18 items). Each item is rated on a 7-point Likert scale (1 = *strongly* *disagree* to 7 = *strongly agree*). The ECR-RD has demonstrated excellent psychometric properties in both clinical and non-clinical German samples (Cronbach's α = 0.91–0.92; Ehrenthal et al., 2009).

Reverse-scored items were recoded prior to subscale calculation. For the avoidant subscale (BVER), items 4, 8, 16, 18, 20, 22, 24, 26, 30, 32, 34, and 36 were reverse-coded. For the anxious subscale (BANG), items 17 and 21 were reverse-coded. Higher scores on each dimension indicate greater levels of attachment-related avoidance or anxiety, respectively. Attachment scores were treated as continuous variables throughout all analyses to preserve statistical power and reflect the dimensional nature of attachment constructs (Fraley et al., 2000)

Positive and Negative Affect Schedule (PANAS): The German version of the PANAS (Breyer & Bluemke, 2016) was used to assess current affective state. The scale consists of two 10-item subscales measuring positive affect (PA; e.g., *aktiv*, *interessiert*, *begeistert*) and negative affect (NA; e.g., *bekümmert*, *verärgert*, *nervös*). Participants rated each item on a 5-point scale (1 = *gar nicht* [not at all] to 5 = *äußerst* [extremely]) based on how they felt "right now, at this moment." The German PANAS has demonstrated high internal consistency (α = .86–.93) and construct validity in representative samples (Breyer & Bluemke, 2016). The PANAS was administered immediately before and after each intervention to capture acute affective changes.

2.3.3 Physiological Stress Measurement

Empatica E4 Wristband: Physiological stress responses were assessed using the Empatica E4 wristband, a research-grade wearable biosensor. The device continuously recorded electrodermal activity (EDA; also known as galvanic skin response, GSR) at a sampling rate of 4 Hz. EDA reflects sympathetic nervous system activation and is sensitive to acute psychological and physiological stressors.

Moments of Stress (MOS): Following the methodology of Kyriakou et al. (2019), "moments of stress" were operationalized as algorithmically detected peaks in EDA signal that exceeded individualized amplitude thresholds. The detection algorithm identifies transient increases in skin conductance (≥ 0.05 µS within a 2-second window) that reflect acute sympathetic activation. MOS frequency (total count per session) served as the primary index of physiological stress in the present study.

Data Quality Control: EDA recordings were required to contain a minimum of 1000 continuous seconds (≈16.7 minutes) of valid, artifact-free data to be included in MOS analyses. This threshold was established through histogram-based analysis of recording durations across all participants and ensured adequate statistical reliability for MOS detection. Sessions with interruptions exceeding 50% of the session duration or total valid data < 1000 seconds were excluded from H2 analyses. Other physiological signals collected by the E4 (heart rate, skin temperature, accelerometry) were not analyzed.

2.3.4 Pain Tolerance Measurement: Dolorimeter/Algometer

A hand-held pressure algometer (Baseline Dolorimeter, 10 kg capacity; Fabrication Enterprises Inc., White Plains, NY) was used to assess mechanical pain threshold. The device applies controlled, gradually increasing pressure (measured in kilograms-force) to a standardized body location (ventral forearm, approximately 5 cm proximal to the wrist).

Participants were instructed to indicate verbally when the sensation transitioned from pressure to pain, at which point the force value was recorded.

Wall Sit Endurance Task: For a subset of participants (n = 26), a wall sit task was employed as a secondary measure of pain-related endurance. Participants were instructed to hold a seated position against a wall with knees bent at 90° for as long as tolerable, with duration recorded in seconds. For statistical analysis, all available pairings (regardless of measurement method) were classified categorically: an increase in pain tolerance was noted when post-intervention values exceeded pre-intervention values ("increase"), and any case where post-intervention tolerance was equal to or less than baseline was marked as "no increase" ("decrease"). This unified approach allowed combining both pain measures for enhanced comparability, while avoiding separate methodological analyses.

2.4 Procedure

2.4.1 Experimental Timeline

Data collection took place between January 20, 2024, and March 10, 2024. Sessions were primarily conducted on weekends (Saturdays and Sundays), with additional sessions on Wednesdays, Thursdays, and Fridays. All sessions occurred between 11:00 AM and 8:00 PM. Room temperature was maintained at a constant 24°C (±1°C) across all sessions to standardize environmental conditions and minimize thermal influences on EDA. No background music was played during any session. Participants disrobed to the upper body only, retaining their trousers throughout; a privacy screen provided a designated changing area, and participants were given the choice to remove their bra before lying down or while already in the prone position, according to their own comfort. A paper towel layer was placed over the waistband to protect clothing from massage oil. A photograph of the room setup is provided in the (Figure 1).

Figure 1. Photograph of the experimental room setup, including the massage table, positioning pillow, and Empatica E4 recording equipment.

2.4.2 Session Structure

Each participant attended two experimental sessions on consecutive days (Day 1 and Day 2). The order of conditions was randomized: Half of the participants received massage on Day 1 (control on Day 2), while the other half received control on Day 1 (massage on Day 2). Each session followed an identical three-phase structure:

Phase 1: Pre-Intervention (≈2-5 minutes)

- Participant arrival and briefing
- Empatica E4 wristband fitted and baseline recording initiated
- ECR-RD questionnaire administered, self-reported menstrual phase question (only on Day 1)
- PANAS questionnaire administered (pre-intervention)
- Empatica E4 wristband recording paused
- Pain tolerance assessment (dolorimeter and/or wall sit)

Phase 2: Intervention (25 minutes)

- Massage condition or Control condition
- Continuous physiological recording via Empatica E4

Phase 3: Post-Intervention (≈5 minutes)

- PANAS questionnaire administered (post-intervention)
- Empatica E4 removed and data saved
- Pain tolerance assessment (dolorimeter and/or wall sit)
- Debriefing and scheduling of Day 2 session

2.4.3 Massage Intervention Protocol

All massage sessions were conducted by the author, a state-certified commercial massage therapist with formal training in classical massage techniques and professional licensing from the Austrian Economic Chamber (WKO). Each massage intervention lasted 25 minutes. The 25-minute duration was selected to balance ecological validity (typical durations in wellness settings range from 30–60 minutes) with experimental control and participant burden. While therapeutic effects of massage are often reported to emerge after 25–30 minutes of application, this duration was deemed sufficient to elicit measurable physiological and affective responses in the context of a standardized research protocol (Baumgart et al., 2011). While no pre-existing standardized protocol for attachment-style-related massage research was available, strict consistency in technique, pressure, duration, and anatomical sequence was maintained across all participants to minimize within-therapist variability.

Technique and Pressure

Classical massage techniques included effleurage (long gliding strokes), petrissage (kneading), and minimal friction. Techniques were applied to major muscle groups of the back, shoulders, neck, and hips. Pressure intensity was standardized to remain below 6 out of 10 on a verbal pain scale (0 = *no pain*, 10 = *unbearable pain*). Participants provided verbal feedback at the beginning of each new anatomical region to ensure adherence to this threshold. Due to this pain threshold constraint, friction techniques were used sparingly to maintain a consistently pleasant experience without pain spikes.

Participants were positioned prone on the massage table with face in the headrest and a pillow under the ankles. Massage oil was applied to the skin prior to manual techniques. The sequence was as follows:

- Overall back (effleurage, introductory strokes): 2 minutes
- Left shoulder and upper back (effleurage, petrissage): 6 minutes
- Right shoulder and upper back (effleurage, petrissage): 6 minutes
- Right lower back and hip (effleurage, petrissage): 5 minutes
- Left lower back and hip (effleurage, petrissage): 5 minutes
- Spine-focused overall back (effleurage, closing strokes): 1 minute

2.4.4 Control Condition Protocol

The control condition consisted of a 25-minute casual conversation without any physical touch. Participants sat upright in a comfortable chair facing the researcher. A standardized conversation protocol was used to ensure consistency across participants while maintaining a naturalistic social interaction. The protocol provided a list of neutral topics (e.g., travel experiences, hobbies, favorite media, sports, weather, ...), and participants were invited to select topics of interest. The conversation followed a semi-structured script to guide the conversation, avoiding emotionally charged or stressful topics. The conversation topic list is provided in the appendix. Participants wore the Empatica E4 wristband throughout the control condition to enable direct comparison of physiological data between conditions.

2.5 Data Processing

2.5.1 Data Preparation

Physiological data from the Empatica E4 were exported using manufacturer software (Empatica E4 Connect). MOS detection was performed using the algorithm described by Kyriakou et al. (2019), with support from Martin Moser (University of Salzburg). The algorithm output a binary indicator (0 or 1) for each second, marking the presence or absence of a stress moment. These binary values were summed to obtain the total MOS count per session. To ensure data reliability, only sessions with at least 1000 seconds (≈16.7 minutes) of valid, artifact-free EDA data were included in H2 analyses. This threshold was established through visual inspection of data duration distributions. Sessions failing to meet this criterion, as well as four cases with MOS values of zero in the Massage condition (identified as measurement errors), were excluded. This resulted in a final sample of n = 30 for H2 analyses.

Menstrual cycle phase was assessed via self-report on Day 1 of the experimental procedure, alongside the ECR-RD questionnaire, and cross-referenced against contraceptive use reported in the initial screening questionnaire. Participants who indicated hormonal contraceptive use were classified as having irregular cycle phase data, as hormonal contraception suppresses endogenous gonadal hormone fluctuations, and were grouped with participants reporting irregular cycles. These cases were excluded from all cycle-phase-based exploratory analyses.

PANAS and pain tolerance data were entered into IBM SPSS Statistics (version 29.0.0, IBM Corp.,2022) for preliminary screening. Delta scores (post – pre) were computed for

PANAS and pain values. Pain tolerance change was dichotomized as "increase" or "no increase." All primary analyses were conducted in RStudio (Version 2024.12.1+563 "Kousa Dogwood"; Posit Team, 2025) using Quarto 1.5.57. Initial data preparation for MOS variables was conducted in Microsoft Excel (Version 2602, Build 16.0.19725.20126; Microsoft Corporation, 2025), prior to further processing in RStudio.

2.5.2 Normality Assessment

Normality of all continuous outcome variables was assessed using Shapiro-Wilk tests and visual inspection of Q-Q plots and histograms. Since violations of normality assumptions (Shapiro-Wilk $p < 0.05$) were observed for several variables but not consistently across all conditions, nonparametric methods were applied uniformly for all paired comparisons to ensure consistency and methodological rigor. Specifically, Wilcoxon signed-rank tests were used for paired comparisons, and Spearman's rank-order correlations were used for association analyses.

2.6 Statistical Analysis

Statistical analyses focused on examining relationships between attachment styles (avoidant and anxious) and intervention responses across two conditions: Massage and Control. Attachment scores were treated as continuous variables throughout all analyses, avoiding artificial dichotomization. This approach preserves statistical power and reflects the dimensional nature of attachment constructs (Fraley et al., 2000).

2.6.1 Primary Analyses

Hypothesis 1 (Affective Responses): Relationships between attachment dimensions and affective outcomes (positive affect, negative affect) were examined using Spearman's rank-order correlations. Correlations were computed separately for post-intervention scores and delta scores (change from baseline) within each condition (Massage, Control). Spearman's rho was selected due to non-normal distributions and the presence of outliers in affective data, as confirmed by Shapiro-Wilk tests. Additionally, Wilcoxon signed-rank tests were used to examine whether pre-to-post changes in positive and negative affect differed significantly from zero within each condition.

Hypothesis 2 (Moments of Stress): Physiological stress responses (MOS) were compared between conditions using paired Wilcoxon signed-rank tests, given violations of normality assumptions (Shapiro-Wilk tests: all $p < 0.05$). The test was two-sided. Effect sizes were calculated as $r = Z / \sqrt{N}$, following Cohen's (1988) guidelines (small: $r \geq 0.10$; medium: $r \geq 0.30$; large: $r \geq 0.50$). Additionally, Spearman correlations assessed relationships between attachment scores (avoidant, anxious) and MOS within each condition, as well as with delta-MOS (Control – Massage) to examine whether attachment style moderated the intervention effect.

Hypothesis 3 (Pain Tolerance): Changes in pain tolerance were operationalized as a binary outcome (increase vs. no increase) based on pre-to-post comparisons. Chi-square tests of independence were used to examine whether the proportion of participants showing pain tolerance increases differed between the Massage and Control conditions, with Cramér's V reported as the effect size. Additionally, binomial logistic regression models were fitted to examine whether avoidant and anxious attachment scores predicted the odds of pain tolerance increases, both across conditions combined and separately for each condition.

2.6.2 Software and Significance

All statistical tests were two-tailed with $\alpha = .05$. Data preprocessing was performed using IBM SPSS Statistics (version 29.0.0; IBM Corp., 2022). Primary analyses, effect size calculations, and visualizations were conducted in RStudio (Posit Team, 2025; Version 2024.12.1+563.) using the R packages effsize (Torchiano, 2016), lsr (Navarro, 2015), and psych (Revelle, 2025).

2.7 Ethical Considerations

All participants provided written informed consent prior to participation. Consent forms detailed the study purpose, procedures, potential risks, confidentiality measures, and the right to withdraw at any time without penalty or explanation. Data were pseudonymized using alphanumeric codes to protect participant privacy; no personally identifying information was linked to experimental data files. The research protocol was reviewed and approved by the institutional ethics committee of the Danube University Krems (Universität für Weiterbildung Krems) prior to data collection.

3 Results

3.1 Sample Characteristics

The final sample consisted of 50 female participants ($M = 26.1$ years, $SD = 2.86$, range: 22–37). Each participant completed both experimental conditions across two consecutive sessions, with condition order counterbalanced across participants (25 per order group). Valid sample sizes varied by hypothesis due to missing or insufficient data: $n = 48$ for affective response analyses (H1), and $n = 30$ for physiological stress analyses (H2), $n = 43$ for pain tolerance analyses (H3); see Methods for exclusion criteria).

Attachment dimensions were assessed using the ECR-RD and treated as continuous variables throughout all analyses. Avoidant attachment scores ranged from 1.06 to 4.83 ($M = 2.35$, $SD = 0.98$, $Mdn = 2.11$) and anxious attachment scores from 1.06 to 5.61 ($M = 3.04$, $SD = 1.20$, $Mdn = 2.89$), indicating adequate variance across both dimensions. Both scores fell below general population norms, consistent with a relatively securely attached convenience sample (see Methods, Sample Characteristics). The two dimensions showed a moderate positive intercorrelation ($r = .49$, $p < .001$).

Two additional sample characteristics were documented for exploratory purposes, as outlined in the introduction. Prior massage experience was limited, the majority of participants, with 74% having received fewer than five massages. Menstrual cycle phases were distributed across menstrual (24%), follicular (18%), ovulation (10%), luteal (22%), and irregular patterns (26%); 20% reported current hormonal contraceptive use. Participants currently using hormonal contraception ($n = 10$, 20%) were grouped with the irregular category for all cycle-phase analyses, as hormonal contraception suppresses endogenous gonadal fluctuations

3.2 Hypothesis 1: Attachment Style and Affective Outcomes

To test whether participants with higher avoidant attachment scores would report significantly lower positive affect and higher negative affect following massage intervention, Spearman rank-order correlations were computed between continuous attachment dimensions (avoidant and anxious from the ECR-RD) and affective outcomes measured by the PANAS. Given the within-subject design, analyses were conducted separately for each condition (Massage and Control) and examined both post-intervention scores and change scores (delta: post minus pre). Additionally, to assess potential item-level effects and rule out response bias related to physiological states (e.g., alertness, awakeness), individual PANAS items were examined, and a principal component analysis (PCA) was performed on the positive and negative affect dimensions to validate the structural integrity of the scales.

3.2.1 Post-Intervention Effects: Attachment and Affective Outcomes

Spearman rank-order correlations were computed between attachment dimensions (avoidant and anxious) and post-intervention affective states (positive and negative affect) for the overall sample as well as separately by condition (Massage vs. Control).

Overall Sample (n = 86)

Across both conditions combined, avoidant attachment showed a significant positive association with negative affect post-intervention ($\rho = .33$, $p = .009$). This indicates that participants with higher avoidant attachment experienced higher negative affect immediately following the intervention. For positive affect no significant association with avoidant attachment ($\rho = -.15$, $p = .538$) was detectable.

Anxious attachment showed no significant correlations with either positive affect ($\rho = -.23$, $p = .121$) or negative affect ($\rho = .13$, $p = .538$) in the overall sample.

Massage Condition (n = 43)

Within the massage condition, no significant correlations emerged between avoidant attachment and affective outcomes. Avoidant attachment showed a moderate positive but non-significant association with negative affect ($\rho = .31$, $p = .207$), and a weak negative but non-significant association with positive affect ($\rho = -.12$, $p = 1.00$). Anxious attachment was not significantly correlated with positive affect ($\rho = -.22$, $p = .608$) or negative affect ($\rho = -.02$, $p = 1.00$) in the massage condition.

Control Condition (n = 43)

In the control condition, avoidant attachment showed a small positive correlation with negative affect ($\rho = .36$, $p = .091$), which did not reach statistical significance. Avoidant attachment was not significantly associated with positive affect ($\rho = -.19$, $p = .459$).

Anxious attachment was not significantly correlated with negative affect ($\rho = .28$, $p = .281$) or positive affect ($\rho = -.27$, $p = .281$). Although the effect size for anxious attachment and positive affect was moderate in magnitude, the association did not achieve statistical significance. Overall, attachment dimensions were not significantly related to affective outcomes in the control condition.

Summary of Post-Intervention Findings

Across conditions, avoidant attachment was the only attachment dimension showing a significant correlation with affective outcomes. In the overall sample, avoidant attachment was significantly correlated with higher negative affect ($\rho = .33$, $p = .009$). When examined separately by condition, this association was stronger in the control condition ($\rho = .36$, $p = .091$) than in the massage condition ($\rho = .31$, $p = .207$), though neither reached conventional significance thresholds individually. Anxious attachment showed no significant associations with positive or negative affect in either condition or in the overall sample.

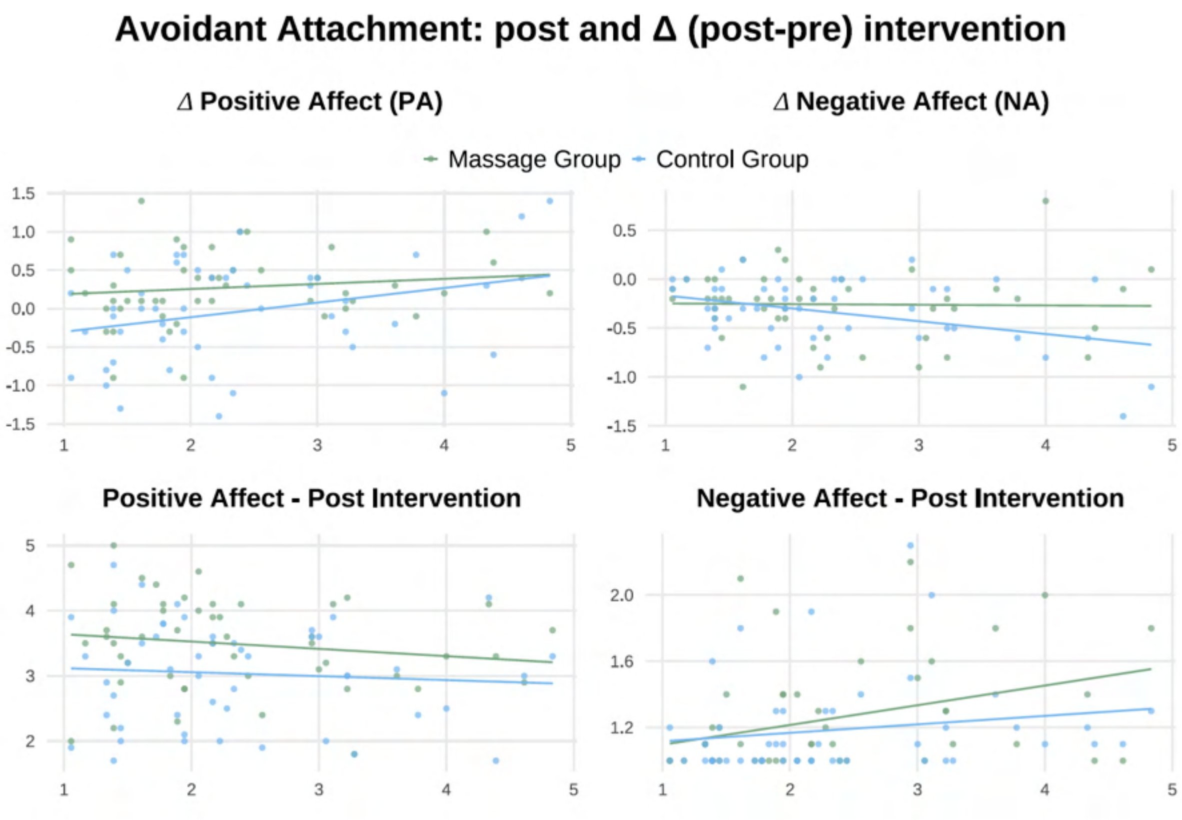


Figure 2. Scatterplots avoidant attachment vs affect change post-intervention

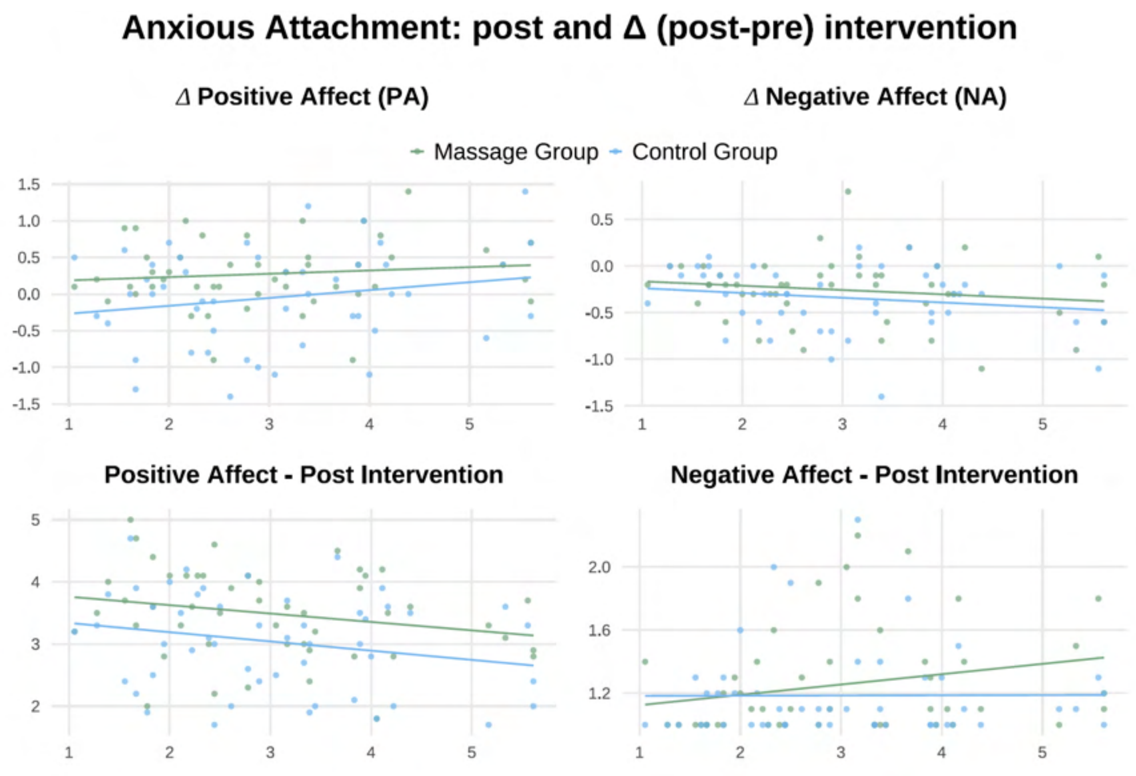


Figure 3. Scatterplots anxious attachment vs affect change post intervention

3.2.2 Change Scores (Delta): Attachment and Affective Change

To examine whether attachment style predicted changes in affective states from pre- to post-intervention, Spearman rank-order correlations were computed between attachment dimensions and change in scores (post minus pre) for positive and negative affect. Analyses were conducted for the overall sample and separately by condition.

Overall Sample (n = 86)

Across both conditions, avoidant attachment showed a trend-level positive association with changes in positive affect ($\rho = .28$, $p = .058$), suggesting that higher avoidant attachment was associated with greater increases in positive affect from pre- to post-intervention (Figure 2). However, this relationship did not reach statistical significance. Avoidant attachment was not significantly associated with changes in negative affect ($\rho = -.18$, $p = .281$). Anxious attachment showed no significant associations with changes in either positive affect ($\rho = .19$, $p = .281$) or negative affect ($\rho = -.17$, $p = .281$).

Massage Condition (n = 43)

Within the massage condition, avoidant attachment was not significantly correlated with changes in positive affect ($\rho = .26$, $p = .398$) or negative affect ($\rho = -.30$, $p = .298$). Similarly, anxious attachment showed no significant associations with positive affect change ($\rho = .22$, $p = .508$) or negative affect change ($\rho = -.20$, $p = .508$).

Control Condition (n = 43)

In the control condition, avoidant attachment was not significantly associated with changes in positive affect ($\rho = .29$, $p = .335$) or negative affect ($\rho = -.10$, $p = .841$). Anxious attachment similarly showed no significant relationships with positive affect change ($\rho = .18$, $p = .771$) or negative affect change ($\rho = -.13$, $p = .841$).

Summary of Change in Affect

In contrast to the significant association between avoidant attachment and negative affect in post-intervention scores, analyses of changes in affect revealed no significant correlations between attachment dimensions and affective change scores. Avoidant attachment showed a marginal positive association with changes in positive affect in the overall sample ($\rho = .28$, $p = .058$), which was not replicated in the massage ($\rho = .26$, $p = .398$) or control ($\rho = .29$, $p = .335$) conditions separately (Figure 3). Anxious attachment was not significantly associated with changes in positive affect (overall: $\rho = .19$, $p = .281$; massage: $\rho = .22$, $p = .508$; control: $\rho = .18$, $p = .771$) or negative affect (overall: $\rho = -.17$, $p = .281$; massage: $\rho = -.20$, $p = .508$; control: $\rho = -.13$, $p = .841$) across any analysis (Figure 2).

3.2.3 Item-Level Analysis of Individual PANAS Emotions

To examine whether the aggregated positive and negative affect dimensions masked differential responses at the item level, mean change scores (delta) were computed for each of the 20 individual PANAS items separately by condition (Massage vs. Control). This analysis was conducted to identify potential condition-specific response patterns that might not be apparent when using only composite PA and NA scores.

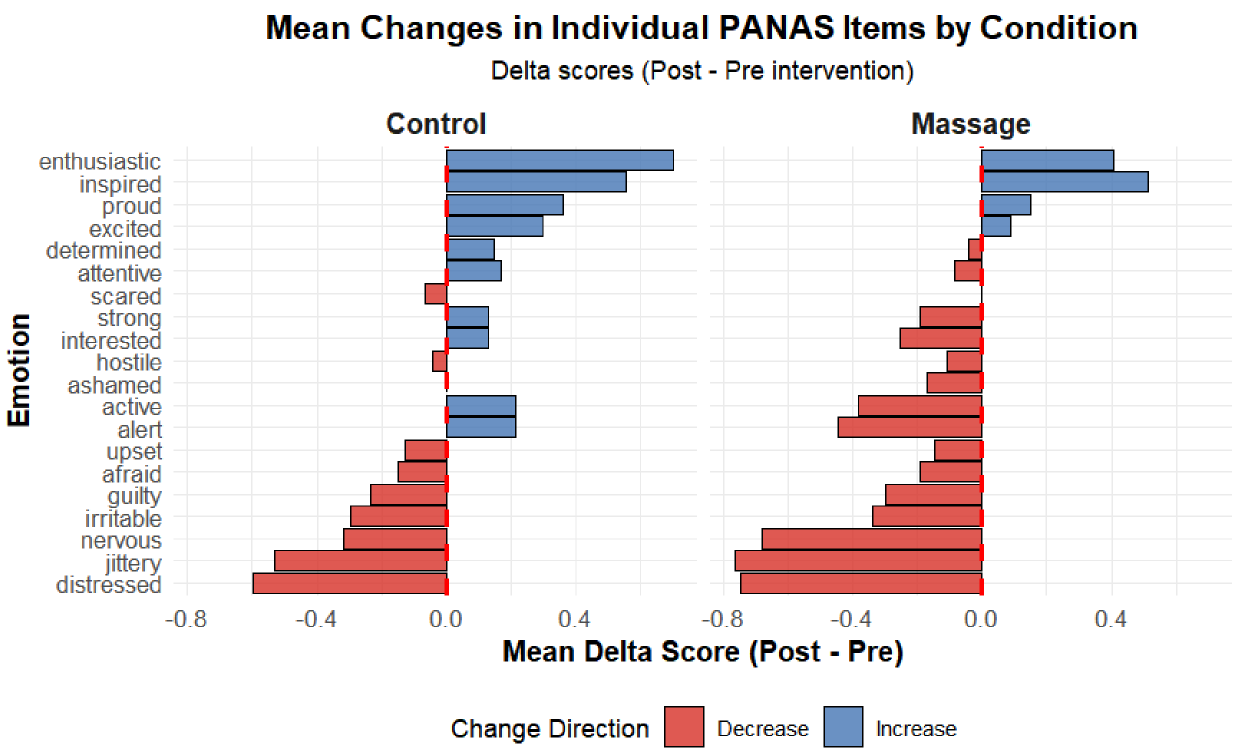


Figure 4. PANAS item-level changes Mean change scores (post minus pre) for individual PANAS emotion items by condition.

As displayed in Figure 4, the two conditions showed notably different emotion trajectories. In the control condition, participants predominantly showed increases in positive emotion items (enthusiasm, inspiration, pride, excitement) and decreases in negative emotion items (distress, jitteriness, nervousness, irritability). In contrast, the massage condition exhibited a more heterogeneous pattern, characterized by increases in several negative affect items (strong, interested, ashamed, guilty, afraid, upset, nervous, irritable, active) alongside variable changes in positive affect items.

These item-level differences suggest that the dimensional structure of emotional experience may differ between conditions. Specifically, some items typically associated with negative affect (e.g., strong, interested) showed directionally opposite patterns in the massage condition compared to the control condition. To formally assess the validity of the standard two-dimensional PANAS structure (positive vs. negative affect) in this dataset, a principal component analysis was conducted.

Principal Component Analysis of PANAS Items

A principal component analysis was performed on the 20 PANAS items to assess the two-factor model (positive and negative affect). The first five components explained 55.2% of total variance, with PC1 accounting for 21.6%, PC2 for 12.4%, and subsequent components declining incrementally (PC3: 8.4%, PC4: 7.0%, PC5: 5.8%). The first two components explained only 34.0% of variance—substantially below the 50–60% threshold for adequate dimensionality reduction in social science research. This pattern reflects the multifactorial structure of PANAS, where individual affective items capture distinct aspects of emotional experience not fully represented by a two-dimensional model. Therefore we did not further pursue this path of analysis.

3.2.4 Affects and Conditions by Menstrual Phase

Across menstrual-status groups, the nonparametric Kruskal–Wallis tests revealed no significant differences in positive affect changes by menstrual status ($H = 7.04$, $p = .134$) or negative affect changes ($H = 1.66$, $p = .798$). Descriptively, mean changes in negative affect ranged from −.23 to −.38 across menstrual-status categories (irregular: $n = 20$, $\Delta NA = -.23$; ovulation: $n = 8$, $\Delta NA = -.26$; menstrual phase: $n = 20$, $\Delta NA = -.38$; follicular phase: $n = 18$, $\Delta NA = -.24$; luteal phase: $n = 20$, $\Delta NA = -.34$). Positive affect changes showed greater variability across menstrual-status groups (irregular: $\Delta PA = .38$; ovulation: $\Delta PA = .29$; menstrual phase: $\Delta PA = .09$; follicular phase: $\Delta PA = .00$; luteal phase: $\Delta PA = -.02$), with sample sizes adequate across all categories except ovulation ($n = 8$). Figure 5 and Figure 6 illustrate the distributions of mean changes in positive and negative affect by menstrual status and condition.

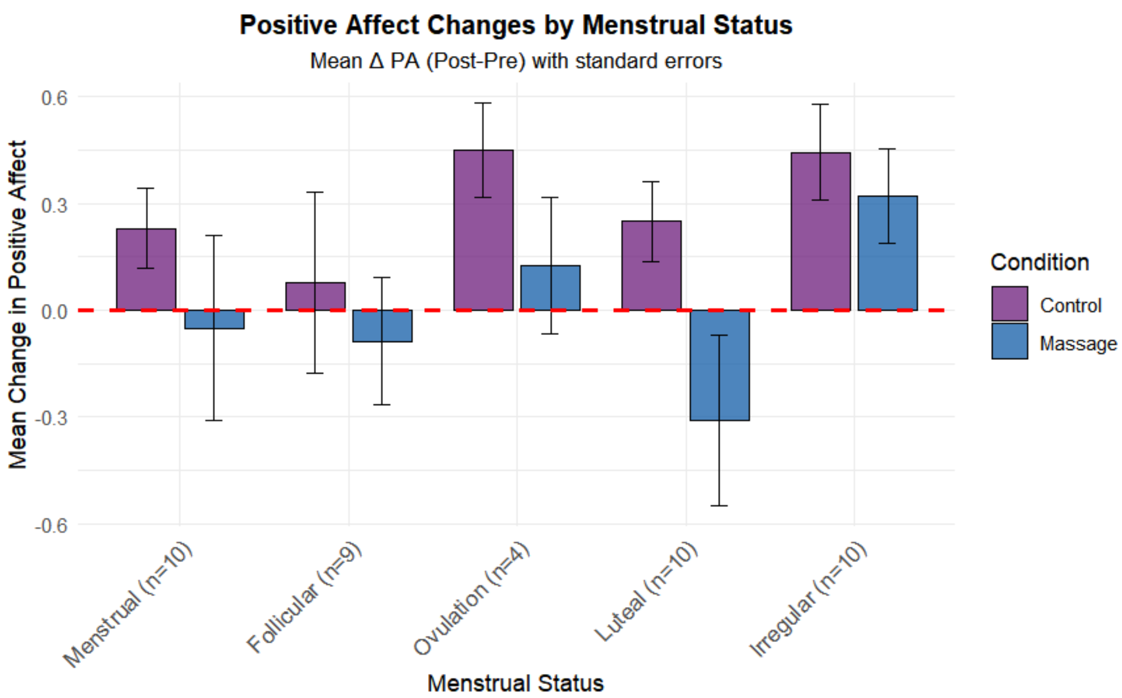


Figure 5. Negative Affect by menstrual phase. Mean change in negative affect (Δ NA; post – pre) by menstrual status and condition (Massage blue vs. Control violet). Bars represent mean change scores; error bars indicate standard errors.

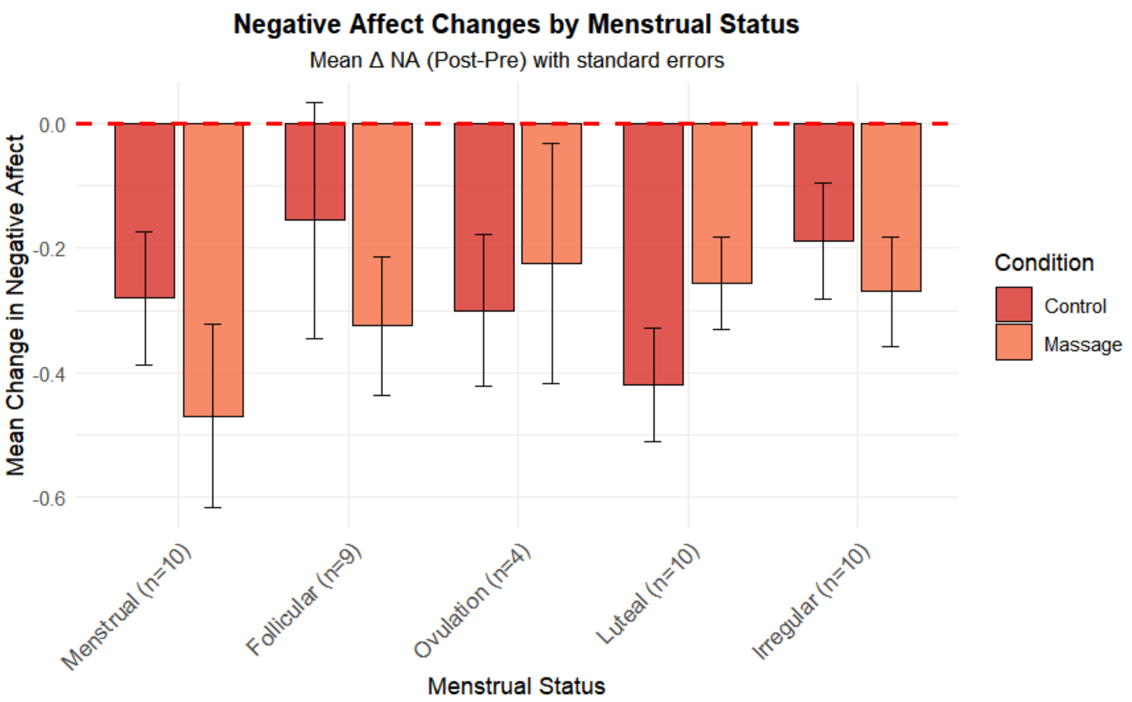


Figure 6. Positive Affect by menstrual phase. Mean change in positive affect (Δ PA; post – pre) by menstrual status and condition (Massage vs. Control). Bars represent mean change scores; error bars indicate standard errors.

3.3 Hypothesis 2: Attachment Style and Physiological Stress (MOS)

Post-intervention Moments of Stress (MOS) were examined to test Hypothesis 2, which predicted that women with higher avoidant attachment would experience more MOS during massage compared to the control condition. MOS were quantified across both conditions for $n = 30$ paired observations using the algorithm by Kyriakou et al. (2019). A paired two-sided Wilcoxon signed-rank test revealed that participants experienced significantly fewer MOS during the massage condition ($Mdn = 12$, $M = 17.53$, $SD = 10.57$) than during the conversation control condition ($Mdn = 27$, $M = 25.7$, $SD = 6.62$), $V = 376$, $p = .003$, $r = .54$), indicating a large effect. Contrary to H2, massage produced robust stress reduction independent of attachment style. To examine potential moderation effects, condition-specific correlations between attachment dimensions and MOS, as well as difference scores (ΔMOS: Control minus Massage), were analyzed.

3.3.1 Post-Intervention Moments of Stress: Massage vs. Control

Moments of Stress differed substantially between conditions (Figure 7). The massage condition showed fewer stress episodes ($Mdn = 12$, $M = 17.53$, $SD = 10.57$) than the control condition ($Mdn = 27$, $M = 25.7$, $SD = 6.62$), with a median difference of 8.5 events.

Overall, total Moments of Stress did not show significant correlations with avoidant attachment ($\rho = -.08$, $p = .55$) and anxious attachment ($\rho = -.04$, $p = .79$), indicating that attachment dimensions were not significantly associated with cumulative stress levels across both conditions.

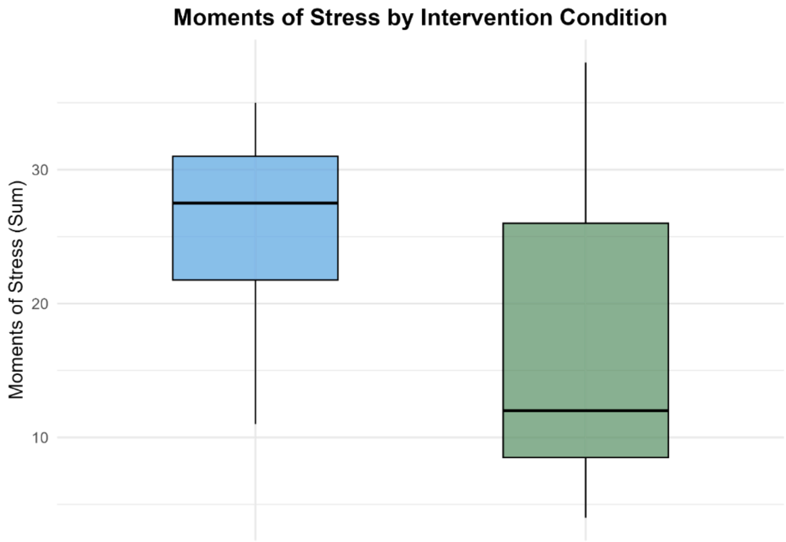


Figure 7. Comparison of Moments of Stress (MOS) between massage (green) and control (blue) conditions.

3.3.2 Attachment Dimensions and Stress Responses by Condition

Correlational analyses examined associations between attachment dimensions and Moments of Stress (MOS) within each condition (Figure 8). In the massage condition, avoidant attachment showed a small non-significant negative correlation with MOS (ρ = –.27, p = .179), and the corresponding scatter plot displayed a downward-sloping trend line consistent with the negative association. Anxious attachment showed a similarly weak, non-significant correlation with MOS in the massage condition (ρ = –.17, p = .397). In the control condition, avoidant attachment (ρ = .09, p = .649) and anxious attachment (ρ = .01, p = .975) were both not associated with MOS, with near-flat trend lines in the corresponding scatter plots. Overall, attachment dimensions were not significantly related to stress responses across conditions.

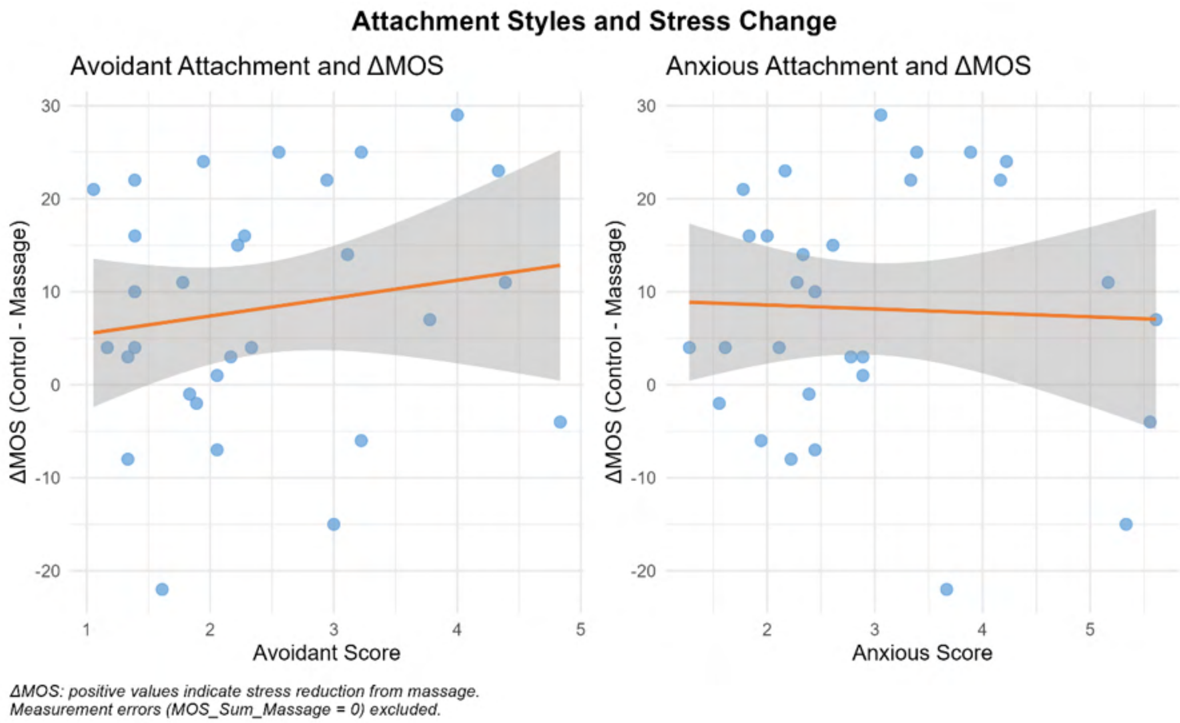


Figure 8. Scatter plots of change in Moments of Stress (ΔMOS: control MOS minus massage MOS) regressed on attachment dimensions. Left panel: avoidant attachment vs. ΔMOS (ρ = .19, p = .321); right panel: anxious attachment vs. ΔMOS (ρ = .09, p = .647).

To examine whether attachment style predicted the magnitude of stress reduction, difference scores (ΔMOS = Control MOS − Massage MOS) were calculated and examined in relation to attachment parameters (Figure 9). Avoidant attachment (ρ = .19, p = .321) and anxious attachment (ρ = .09, p = .647) showed no significant associations with the magnitude of stress reduction. The scatter plots displayed broad point distributions around the regression lines in both panels of Figure 8, reflecting substantial individual variability in stress-reduction responses.

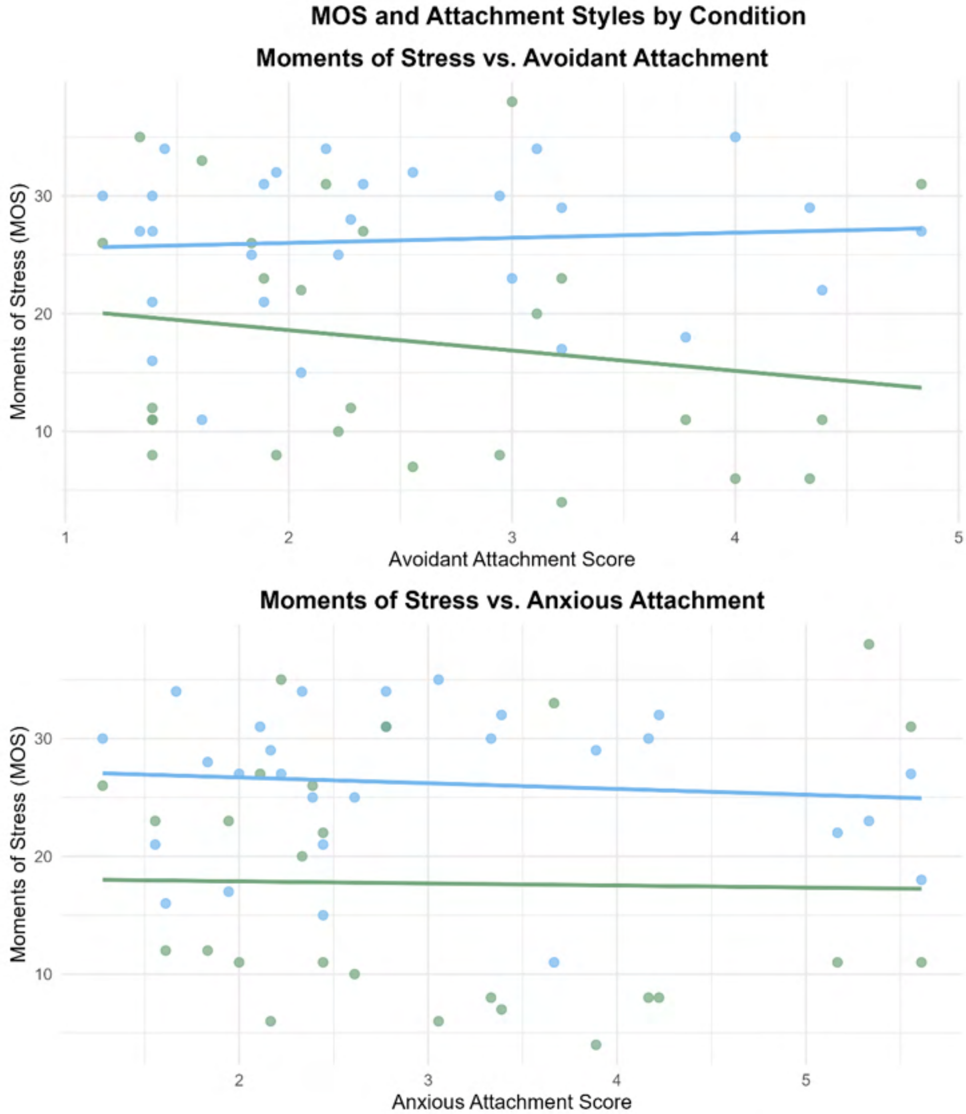


Figure 9. Scatter plots of MOS vs. attachment dimensions by condition (massage: green; control: blue). Top: avoidant attachment (massage ρ = –.27; control ρ = .09). Bottom: anxious attachment (no significant associations).

3.3.3 Summary

Avoidant attachment showed no correlation with MOS in the massage condition (ρ = –.27, p = .179), inconsistent with the hypothesized positive association. Anxious attachment was not significantly associated with MOS in any condition or overall analysis. Massage was associated with substantially fewer moments of stress relative to the control condition (Mdn difference = 8.5 events) across the full sample, independent of attachment orientation.

3.4 Hypothesis 3: Change in Pain Tolerance

A chi-square test of independence revealed no significant association between condition and pain tolerance change, $\chi^2(1) = 1.244$, $p = .265$, $V = .12$, indicating that the proportion of participants showing increased pain tolerance did not differ significantly between the massage (n = 24/43, 56%) and control conditions (n = 30/43, 70%), shown in Figure 10. Prior to analysis, expected cell frequencies were examined; all exceeded 5, satisfying the assumptions for the chi-square test.

Changes in Pain Tolerance from Pre- to Post-Intervention by Condition

Δ Pain Tolerance	Control	Massage
decrease	13	19
increase	30	24

Table 1. Note: n = 43 refers to the number of participants per condition (within-subject design; total observations = 86).

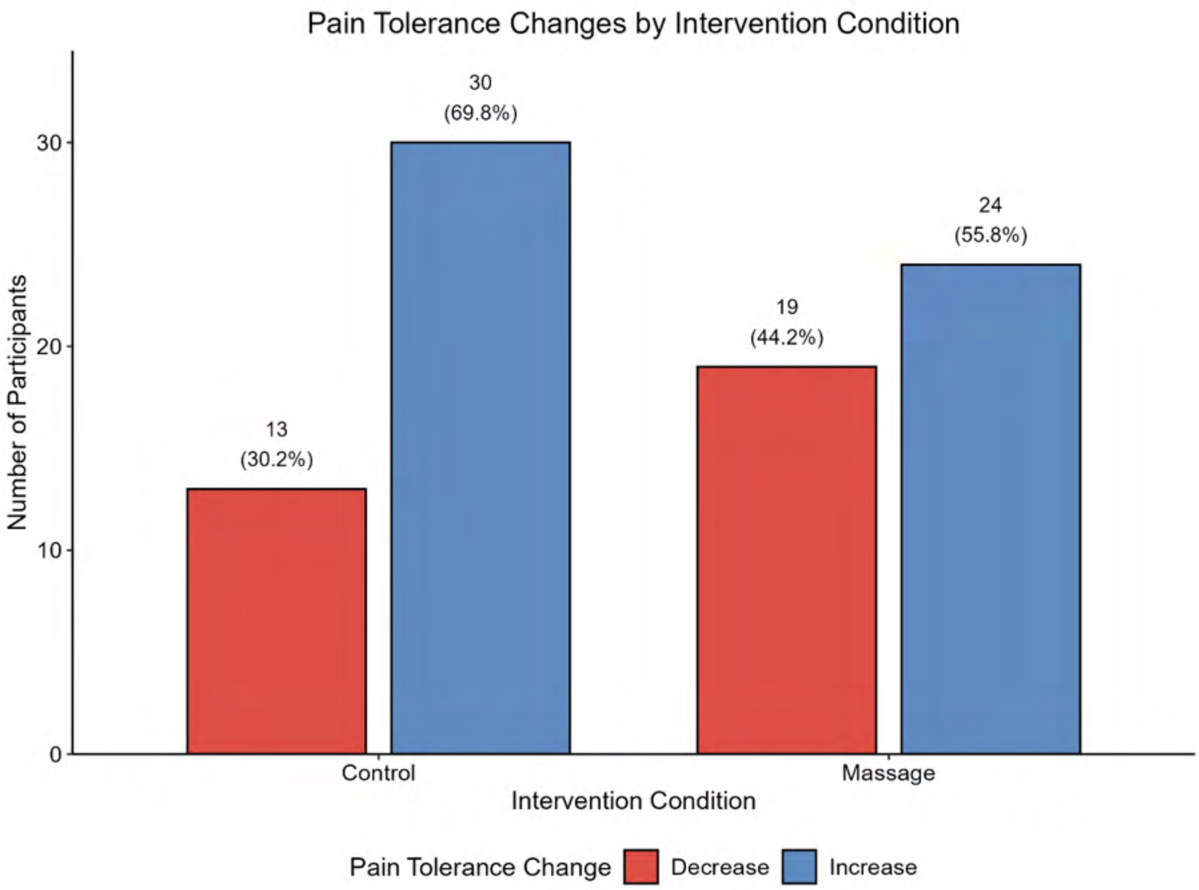


Figure 10. Changes in Pain Tolerance by Condition, Number of participants showing decreased (red) or increased (blue) pain tolerance from pre- to post-intervention in massage and control conditions. Within-subject design (n = 43 per condition.

3.4.1 Binomial Logistic Regression: Attachment Style and Pain Tolerance

Binomial logistic regression models were fitted to examine whether anxious or avoidant attachment styles predicted a change in pain tolerance following the intervention. An initial model was fitted to the full sample to assess overall attachment effects.

Subsequently, separate models were estimated for the massage and control conditions to explore whether these associations varied by condition.

Among participants with complete paired pain tolerance data (n = 43 participants, 86 observations), a logistic regression model testing avoidant attachment, anxious attachment, and condition (Massage vs. Control) as predictors of pain tolerance increase revealed no significant effects. Avoidant attachment did not significantly predict pain tolerance outcomes (OR = .79, 95% CI [.47, 1.31], p = .358). Anxious attachment similarly showed no significant association (OR = 1.31, 95% CI [.87, 2.05], p = .214). Condition was not significantly associated with pain tolerance outcomes (OR = .54, 95% CI [.22, 1.31], p = .178). All confidence intervals included unity, indicating negligible effects across all predictors.

Separate logistic regression models were fitted for each condition. In the massage group (n = 43), neither anxious attachment (OR = 1.26, 95% CI [.72, 2.31], p = .431) nor avoidant attachment (OR = .82, 95% CI [.40, 1.63], p = .566) significantly predicted the odds of increased pain tolerance. In the control group (n = 43), anxious attachment (OR = 1.38, 95% CI [.75, 2.77], p = .327) and avoidant attachment (OR = .75, 95% CI [.35, 1.61], p = .463) likewise showed no significant associations with pain tolerance outcomes (Figure 11).

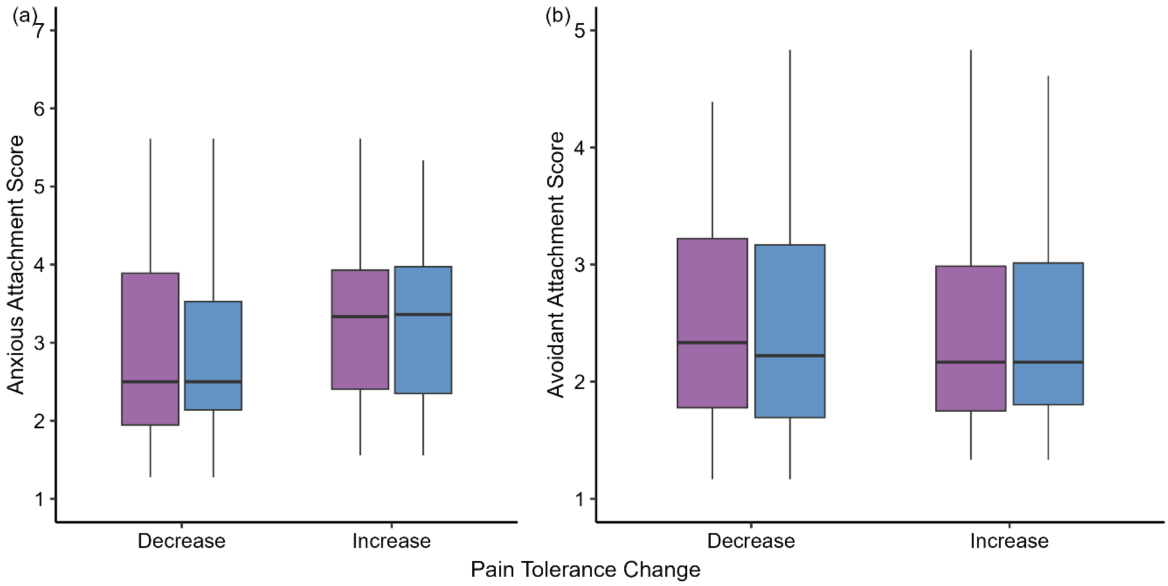


Figure 11. Distribution of (a) anxious and (b) avoidant attachment scores by pain tolerance outcome (Decrease vs. Increase). Purple boxes = Control condition; blue boxes = Massage condition (n = 43 per condition). Higher scores reflect greater attachment anxiety (fear of abandonment) and greater attachment avoidance (discomfort with closeness).

3.4.2 Summary

Chi-square tests and binomial logistic regression analyses yielded no significant results for pain tolerance. The proportion of participants showing a pain tolerance increase did not differ between conditions, and neither attachment dimension predicted pain tolerance outcomes in any analysis. Methodological considerations relevant to these findings are addressed in Section 4.3.2.

4 Discussion

4.1 Hypothesis Findings

This study investigated whether classical massage produces differential effects on pain tolerance, emotional well-being, and physiological stress in women with varying attachment styles. Attachment style did not predict pain tolerance responses to massage, and physiological stress decreased universally across attachment profiles. Affective outcomes, however, showed attachment-related associations that appeared independent of intervention type. Massage reduced physiological stress regardless of attachment style, while attachment organization shaped affective rather than pain-related or autonomic responses.

4.1.1 H1: Affective Responses and Attachment

H1 predicted that women with avoidant attachment would report lower positive affect following massage than women with non-avoidant attachment. This prediction was based on findings that avoidant individuals report fewer positive attitudes toward intimate touch (Bowling et al., 2024) and show blunted activation of reward-related brain regions in response to comfort stimuli (Comte et al., 2024), suggesting a generally reduced hedonic responsiveness to social stimulation.

The results do not support H1 in its primary formulation. Avoidant attachment was not significantly associated with post-intervention positive affect, either across the overall sample or within the massage condition specifically. Change score analyses revealed only a non-significant trend: higher avoidance was weakly associated with greater increases in positive affect from pre- to post-intervention. This direction is counterintuitive relative to H1 and should be interpreted with caution. One interpretation consistent with the MOR framework is that avoidant individuals habitually suppress interoceptive awareness of social reward signals (Nummenmaa et al., 2015). Massage may bypass the relational appraisal processes through which social signals are typically down-regulated, producing a mild increase in positive affect through bottom-up bodily arousal. Given the non-significant result, this remains speculative and should not be over-interpreted. Anxious attachment showed no significant associations with post-intervention affect, nor with affect change scores, across any analysis. Pre-intervention negative affect showed a marginal positive association with anxious attachment in the overall sample, suggesting a comparable dispositional baseline pattern.

An notable pattern emerged with respect to negative affect (NA) . Avoidant attachment was significantly associated with higher post-intervention NA levels across both conditions combined, with more avoidant participants exhibiting persistently elevated negative affect. This association reflects NA level rather than change scores, meaning it captures a stable affective state rather than differential reactivity to the intervention. The association appeared descriptively stronger in the control condition than in the massage condition, though neither reached conventional significance individually.

This pattern is directionally consistent with Krahé et al. (2016), who showed that CT-afferent stimulation of hairy skin partially attenuated avoidance related nociceptive reactivity at the N2 level, while no equivalent effect emerged under stimulation of the non-CT-containing palm. This suggests that CT-based touch can marginally reduce the expression of avoidance-related central reactivity, without resolving the underlying trait-level negativity bias. The present finding, in which avoidance-related negative affect appeared descriptively weaker in the massage condition than in the non-tactile control, aligns with this account. Given the non-significant condition effects and the range restriction in avoidance scores noted in section 4.3.1, this observation warrants replication rather than strong interpretive weight.

Consistently, Tammilehto et al. (2023) found that attachment avoidance predicted lower baseline positive emotions, with no associations emerging for emotional variability or inertia after controlling for baseline. The present data extend this finding: pre-intervention PA was lower and pre-intervention NA was elevated in more avoidant participants, and both differences persisted into post-intervention scores without significant moderation of change scores in either condition. The opioidergic framework of Nummenmaa et al. (2015) offers a mechanistic account: lower MOR availability in more avoidant individuals reduces chronic social hedonic capacity, producing a negativity bias that a single session cannot fully attenuate. This interpretation is taken up in section 4.2.

4.1.2 H2: Moments of Stress

H2 predicted that women with higher avoidant attachment would experience more Moments of Stress during massage than women with non-avoidant attachment, based on the expectation that structured interpersonal touch would be experienced as aversive by avoidant individuals, producing heightened rather than reduced sympathetic activation. Physiological stress was operationalized via algorithmically detected Moments of Stress in the EDA signal, an approach that provides condition-level comparisons independent of subjective report and yields directionally consistent results from wrist-based recordings (Chatel-Goldman et al., 2014; van Dooren et al., 2012; Kyriakou et al., 2019).

The results do not support H2. Avoidant attachment did not predict higher MOS during massage; the direction was in fact opposite to that hypothesized, with higher avoidance weakly associated with fewer stress moments. Anxious attachment showed no significant association with MOS in the massage condition, and neither attachment dimension predicted delta-MOS, indicating that attachment style did not moderate condition-related change in physiological stress.

Beyond the primary hypothesis test, an exploratory comparison revealed that massage was associated with substantially fewer MOS than the conversational control across the full sample, constituting a large effect. This universal stress reduction showed no attachment moderation: neither avoidant nor anxious attachment predicted MOS in the control condition, indicating that the effect was independent of relational orientation. This finding challenges the notion that attachment-dependent deficits in social regulation would extend to physiological stress buffering. The regulatory effects of classical massage appear to operate through bottom-up somatosensory mechanisms, specifically the co-activation of mechanoreceptors and A-beta afferents, which promote parasympathetic tone via pathways that do not depend on the relational meaning assigned to the touch. The mechanistic basis for this interpretation is elaborated in section 4.2

A secondary observation within the MOS analyses merits brief consideration. In the massage condition, avoidant attachment showed a small, non-significant negative association with MOS ($\rho = -.27$, $p = .179$), while in the control condition the corresponding association was near zero ($\rho = .09$, $p = .649$). Although neither coefficient reached conventional significance thresholds and the difference between conditions was not formally tested, this directional divergence is worth noting in the context of condition design. The control condition consisted of a 25-minute conversation with an unfamiliar researcher, a social scenario that differs from neutral rest precisely in that it involves sustained interpersonal proximity, verbal reciprocity, and implicit social evaluation demands. For individuals higher in attachment avoidance, who tend to exhibit heightened vigilance in novel interpersonal contexts and reduced proximity-seeking behaviour (Bowling et al., 2024; Comte et al., 2024), structured social interaction with a stranger may itself constitute a mild activating condition rather than a neutral baseline. If so, the control condition may have partially elevated sympathetic arousal in more avoidant participants, contributing to the elevated overall MOS count observed in that condition. This interpretation does not alter the primary finding of a universal MOS reduction following massage, but it raises the possibility that a genuinely passive rest condition without interpersonal interaction would more cleanly isolate the stress-reducing properties of tactile contact. This consideration is taken up in the design recommendations in section 4.4.

4.1.3 H3: Pain Tolerance

H3 predicated that women with avoidant attachment would not show significant increases in pain tolerance following massage. This prediction was grounded in the neurophysiological finding that, under CT-afferent stimulation of the hairy forearm, higher attachment avoidance predicts heightened rather than reduced early nociceptive processing (Krahé et al., 2016), suggesting that CT-based social touch activates associations of social unavailability in avoidant individuals and thereby maintains rather than down-regulates perceived threat. At an attitudinal level, higher attachment avoidance is also associated with less positive orientations toward intimate touch (Bowling et al., 2024), indicating a broader disengagement from close tactile contact. Meredith (2013), reviewing eight experimental pain studies, found that avoidantly attached individuals showed reduced benefit from social presence during pain induction and expressed preferences for being alone during painful experiences. This indicates a broader pattern of reduced reliance on interpersonal contact for pain regulation that is consistent with the reasoning behind H3. Romeo et al. (2017), reviewing nine studies on attachment and chronic pain, extend this pattern: avoidant individuals reported higher pain intensity, greater catastrophizing, and reduced social coping, while anxious attachment was associated with heightened pain-related behaviour.

Contrary to this hypothesis, the present study found no significant association between attachment style and pain tolerance outcomes. Neither chi-square analysis nor logistic regression supported the predicted association, and equivalent null findings emerged in both conditions separately.

Before attributing the null findings to the intervention itself, it is important to note that the result is directionally consistent with prior neurophysiological work. The predicted direction for H3 was not a reduction in pain tolerance for avoidant individuals per se, but rather an absence of the increase that might be expected in more securely attached individuals. This is coherent with Krahé et al. (2016), where avoidance predicted heightened rather than reduced nociceptive N1 responses specifically under CT-optimal touch to hairy skin, the tissue types most comparable to the back and shoulders targeted in classical massage. The broader literature consistently documents analgesic effects of massage (Crawford et al., 2016; Moyer et al., 2011; Liljencrantz et al., 2017), and the present findings do not contradict this: The endorphin-mediated and CT-afferent-driven regulatory mechanisms established in the theoretical framework remain plausible here. Rather, the absence of a detectable pain shift is more plausibly attributed to the sensitivity constraints of the measurement approach, which are addressed in detail in sections 4.3.1 and 4.3.2 . Nunes et al. (2016) reported significant massage-induced reductions on self-report pain measures but no significant algometric effect in a healthy sample, a pattern also illustrated by Danner et al. (2025), who documented significant pain reduction following a single 20-minute massage in healthy adults, further suggesting that algometric assessment may lack sufficient sensitivity to detect pain changes in non-clinical samples. Farber & Wieland (2016) found the most consistent algometric effects in populations with elevated baseline pain, where the detectable range of change is substantially wider. Studies documenting robust algometric effects typically employed repeated sessions in clinical populations (Moyer et al., 2011), synchronized group activity paradigms (Tarr et al., 2015), group laughter as a proxy for endorphin release (Dunbar et al., 2021), or intimate partner touch with neuroimaging mu-opioid modulation (Nummenmaa et al., 2016). The exclusively female sample additionally removes between-participant variance attributable to the documented sex difference in pressure pain threshold, whereby women exhibit lower mean PPT values than men across measurement sites (Chesterton et al., 2003). An additional confound specific to the wall-sit subsample is addressed in section 4.3.2.

4.2 Integration: Two Divergent Regulatory Pathways

The present data are consistent with a mechanistic divergence between two partially independent pathways. A peripheral somatosensory pathway produces universal regulatory benefits, while a central affective pathway shows sensitivity to attachment organization. The following sections examine each pathway in turn before addressing pain tolerance and applied implications.

4.2.1 The CT-Afferent Pathway: Universal Parasympathetic Regulation

CT-afferents project to the posterior insular cortex and subsequently modulate parasympathetic tone via vagal pathways (Björnsdotter et al., 2009; McGlone et al., 2014, Müller-Oerlinghausen et al., 2022). Although CT-afferents respond optimally to light stroking rather than deep pressure, effleurage strokes in classical massage operate at velocities and skin coverage that partially engage CT-afferent pathways alongside mechanoreceptors and A-beta afferents (Field, 2019; McGlone et al., 2014), with both pathways shown to operate in concert rather than in isolation (Case et al., 2023; see Section 1.3.3). The standardized massage protocol employed here maintained consistent, moderate pressure and systematic stroking of back muscles, parameters consistent with the velocity range known to preferentially engage these afferents. The most direct support for this pathway comes from the MOS findings in section 4.1.2: The substantial, universal reduction in sympathetically driven stress events was entirely unrelated to either attachment dimension. The absence of any attachment modulation across all MOS analyses supports the interpretation that CT-afferent-mediated parasympathetic engagement represents a bottom-up mechanism robust to individual differences in relational history.

Additionally, Krahé et al. (2016) demonstrated that avoidance-related augmentation of nociceptive N1 responses occurred specifically under CT-optimal stimulation of hairy skin but not glabrous skin, further indicating that CT-afferent engagement itself is not blocked in avoidant individuals. What differs is the relational appraisal, while the peripheral regulatory channel remains operative. Krahé et al. (2018) specified this pattern at the behavioural level: Insecure attachment was associated with reduced discrimination between CT-optimal and non-CT-optimal touch in terms of perceived pleasantness. Importantly, both groups rated CT-optimal touch as significantly more pleasant than non-CT-optimal stimulation. This indicates that the hedonic signal carried by CT-afferent stimulation reaches individuals across attachment classifications, consistent with the universal MOS reduction observed in section 4.1.3.

A relevant study from Case et al. (2023), demonstrated that blocking mechanoreceptive Aβ-fiber function nearly abolished the pleasantness of gentle stroking, indicating that the hedonic signal carried by slow stroking requires intact Aβ-fiber input and is not conveyed through CT-afferents alone. This does not preclude a functional role for CT-afferent activation in the parasympathetic effects observed here, but it suggests that the peripheral basis of touch-induced regulation is more distributed than a strict CT-only account implies.

4.2.2 The MOR-Mediated Pathway: Attachment-Sensitive Affective Processing

The second pathway operates through MOR-mediated social hedonic processing. Touch stimulates endogenous opioid release, and the resulting affective reward signal is processed via MOR availability across the insula, thalamus, striatum, and cingulate cortex (Nummenmaa et al., 2015; Turtonen et al., 2021). Higher attachment avoidance is associated with lower MOR availability in these regions, meaning that the same tactile input produces a weaker hedonic response. This is not a perceptual deficit but a difference in affective signal amplification operating at the level of social cognition and emotional appraisal rather than peripheral sensation.

The affective findings in section 4.1.2 are interpretable within this framework. Avoidant attachment predicted significantly elevated negative affect both before and after intervention across conditions but did not predict change scores in either condition. This distinction between post-intervention levels and intervention-induced change is precisely what chronically reduced MOR-mediated social hedonic capacity would predict. A persistently elevated negativity bias would not be fully overcome by a single 25-minute session. The opioidergic channel through which touch ordinarily produces lasting affective uplift is structurally dampened in these individuals. The descriptively weaker negative-affect association in the massage condition relative to the control condition is directionally consistent with the interpretation that structured tactile contact may marginally engage this otherwise dampened opioidergic channel, though this observation requires replication before stronger conclusions can be drawn.

4.2.3 Pain Tolerance: Within the Two-Pathway Model

The pain tolerance findings described in section 4.1.3 do not straightforwardly fit either system. The null findings are more directly attributable to the methodological constraints documented in sections 4.3.1 and 4.3.2 than to the absence of a genuine analgesic pathway and therefore do not disconfirm either regulatory system.

4.2.4 Applied Implications and Generalizability

The physiological stress-buffering properties of classical massage appear accessible across attachment profiles. This points toward its potential utility as a transdiagnostic, bottom-up regulatory approach even for individuals who tend to disengage from interventions that rely on interpersonal contact. This clinical rationale is supported by Müller-Oerlinghausen et al. (2022), who argue that slow-stroke massage engaging CT afferents and oxytocinergic pathways offers a non-verbal, body-level access route capable of bypassing the cognitive and relational defensive processes characteristic of avoidant and anhedonic presentations. Controlled evidence across psychiatric, oncological, and geriatric populations supports generalizability across clinical settings and populations.

A relevant qualification concerns these findings beyond the laboratory setting. In naturalistic practice, touch-based interventions unfold across repeated sessions within an established therapeutic relationship, conditions that may matter particularly for avoidant individuals: the interpersonal novelty of a single session with an unfamiliar researcher may itself constitute a source of social vigilance (Bowling et al., 2024; Comte et al., 2024) that partially masks attachment-related modulation. Whether the regulatory effects documented here accumulate or differentiate over repeated, relationally embedded sessions remain an open empirical question.

4.3 Methodological Considerations and Limitations

4.3.1 Sample Composition and Avoidance Range Restriction

A relevant limitation concerns the distribution attachment styles within the sample. Detecting moderation effects requires sufficient representation of avoidant individuals, yet both anxiety and avoidance scores fell below population norms for women (Fraley, 2012), indicating limited representation of the insecure end of both attachment dimensions. Range restriction of this kind attenuates observed correlations independent of true population-level effects (Miciak et al., 2016). This makes it statistically unlikely that moderation would reach significance even if a genuine effect exists in the broader population. Future studies should therefore consider targeted recruitment of insecure attachment profiles, or sampling from clinical populations with elevated rates of avoidant and anxious attachment, such as individuals presenting with chronic stress or somatic symptom disorders.

4.3.2 Pain Instrument Transition

A primary methodological challenge arose from an unplanned device failure that required a mid-study transition from the pressure algometer to the wall-sit-hold task for approximately half the sample. The two instruments differ substantially in the type of tolerance they assess: Mechanical pain threshold versus muscular endurance under sustained discomfort.

Analyses focused on directional change from pre- to post-intervention within each measure rather than absolute values, as the protocol did not hypothesize differences between the two instruments. This categorical approach preserved statistical power despite non-normal distributions and was consistent with the primary hypothesis testing framework. It did, however, preclude examination of effect magnitude, meaning that genuine but small nociceptive shifts gone undetected.

Further consideration applies specifically to the wall-sit subsample. Participants in the massage condition appeared to exert notably reduced effort compared to the control condition. Informal feedback from several participants suggested a deliberate reluctance to engage maximally, as they did not wish to counteract the relaxed state induced by the massage. This was not formally assessed and cannot be treated as systematic evidence. It does, however, raise the possibility that the wall-sit captured reluctance to disrupt post-massage comfort rather than actual pain tolerance. Johnson and Dunbar (2016) employed the wall-sit as a proxy for mu-opioid system activation in a social bonding context and found that pain tolerance significantly predicted social network size, which suggests the task is to opioidergic modulation under appropriate motivational conditions. The limitation in the present design is therefore not the instrument, but the absence of standardized motivational instructions held constant across conditions. The algometer requires only brief passive tolerance of incrementally increasing pressure and represents a more suitable instrument for future designs.

Future studies using the wall-sit should include standardized motivational instructions held constant across conditions. As noted in section 4.1.1, the exclusively female sample additionally removes the documented sex difference in pressure pain threshold as source of between-participant variance.

4.3.3 Control Condition Design and Ecological Validity

The conversational control condition was selected over passive rest for a specific theoretical reason: clinical massage inherently involves verbal therapist-client interaction to establish trust and safety (McParlin et al., 2022), and replicating this relational context in the control condition was necessary to isolate touch-specific effects from the social components of the intervention. A silent, non-interactive control would have introduced social discomfort with an unfamiliar researcher, particularly for participants with insecure attachment, for whom interpersonal novelty with a stranger can itself constitute a source of social vigilance (Bowling et al., 2024; Comte et al., 2024), thereby confounding the variable of interest.

However, this design choice simultaneously precluded clean isolation of tactile from social regulatory components. The observation that the control condition showed pain-tolerance increases comparable to massage suggests that the two conditions were insufficiently differentiated on at least this behavioural outcome. While PANAS outcomes showed no significant between-condition differences, the MOS analysis documented a large physiological effect favouring massage over the conversational control. This is consistent with Meier et al.'s (2020) observation that massage-specific effects are more reliably indexed at the physiological than the self-report level. It should be noted, however, that the present study assessed sympathetic arousal via EDA rather than HF-HRV, and compared against an active conversational rather than a passive rest control.

An passive rest control arm would have provided a stronger basis for comparison. Future studies should employ a three-arm design to triangulate tactile, social, and rest-specific contributions to observed effects, as detailed in section 4.5.1.

4.3.4 Questionnaire Selection and the Structural Limits of the PANAS

A central measurement limitation concerns the structural adequacy of the PANAS as the primary affective outcome instrument. A principal component analysis on the 20 PANAS items yielded a two-factor solution accounting for only 34.0% of total variance (PC1: 21.6%; PC2: 12.4%), substantially below the 50–60% threshold generally regarded as adequate for dimensionality reduction in social science research (Jolliffe, 2002; Kaiser, 1960). The standard positive and negative affect composites therefore appear to have masked meaningful item-level variation in this sample. Item-level analysis revealed divergent emotional trajectories across conditions: in the control condition, positive affect items (e.g. enthusiasm, inspiration, excitement) predominantly increased while negative affect items (e.g. distress, nervousness, irritability) decreased; in the massage condition, a more heterogeneous pattern emerged, with several items within the negative affect subscale, such as "strong" and "interested," showing increases alongside variable changes on positive affect items. This pattern is consistent with the interpretation that massage induced an activated, aroused form of relaxation that the standard two-dimensional scoring does not adequately differentiate from global positive affect. The PANAS also lacks items directly indexing relaxation, bodily calm, or the vigour-fatigue continuum, dimensions that are theoretically central to a massage-specific affective signature. Rapaport et al. (2016) documented condition-specific effects at precisely these subscale levels using the Profile of Mood States (POMS), particularly for fatigue-inertia (effect size = -0.657, p = .009).

Supplementing or replacing the PANAS with the POMS-2 in future studies would substantially improve affective sensitivity. Danner et al. (2025) provide direct support for this recommendation: using the Bf-SR, a German mood instrument with comparable sensitivity to the POMS-2, they documented significant mood improvements following a single 20-minute full-body massage in healthy adults relative to a passive control condition (r = 0.70), underscoring that massage-induced mood modulation can be reliably detected with appropriate instruments even within a single-session design. Sumioka et al. (2013) found no significant PANAS changes following a touch intervention despite a significant cortisol reduction, illustrating more broadly that physiological regulation and self-reported positive affect do not necessarily co-occur in response to touch. Taken together, the null PA findings of the present study are better attributed to instrument insensitivity than to a genuine absence of affective differentiation, a limitation that applies directly to the interpretation of H1.

4.3.5 Single-Therapist Design and Researcher Confound

All massage sessions were conducted by the lead researcher, a state-certified massage therapist licensed by the Austrian Economic Chamber (WKO), ensuring procedural standardization to technique, pressure, duration, and anatomical sequence. Within the present within-subject design, therapist identity was held constant across both conditions, effectively controlling for individual differences in therapeutic style and non-verbal communication. However, this design cannot exclude the possibility that participants varied in their affective response to this specific therapist independently of the intervention. Distributing sessions across multiple certified therapists in future studies would address this limitation, while introducing potential variation through differences in manual therapy. The potential role of therapist-participant rapport as an independent moderator of touch-based outcomes could be assessed through standardized post-intervention rapport measures.

4.3.6 Massage Protocol Fidelity

The massage protocol was standardized in technique sequence, anatomical coverage, duration, and pressure threshold (below 6/10 on a participant-reported pain scale). Stroke velocity was not formally measured during sessions; however, effleurage structurally involves slow, gliding strokes that correspond to the naturalistic touch pattern to which CT-afferents are preferentially tuned, with peak responsiveness in the range of approximately

1 to 10 cm/s (McGlone et al., 2014; Löken et al., 2009). This is consistent with the argument developed in section 4.2 that classical massage and CT-afferent engagement are structurally convergent rather than arbitrarily separable. Objective velocity measurement via motion capture or pressure-sensitive instrumentation in future studies would nonetheless allow direct quantification of this overlap and strengthen the mechanistic interpretability of observed physiological outcomes.

4.4 Implications for Research and Practice

The present findings suggest that classical massage produces substantial stress reduction across attachment orientations. This supports the potential value of somatosensory-based interventions as an attachment-independent regulatory tool. This is theoretically relevant for individuals with avoidant attachment, who may show lower engagement with interpersonally mediated approaches such as psychotherapy or verbal coaching, but may be more receptive to the non-demanding, bottom-up physiological regulation that structured touch can offer.

The universal MOS reduction documented here suggests that classical massage may be particularly well-suited as a transdiagnostic entry-level intervention in stress-reduction contexts, such as psychosomatic rehabilitation or burnout prevention, because its physiological regulatory effects do not presuppose the relational engagement that interpersonally delivered approaches typically require.

4.5 Future Research Directions

4.5.1 Three-by-Two Factorial Design

The most pressing structural limitation of the present design is the inability to disentangle tactile from social and verbal components of the intervention. A three-by-two factorial design would address this directly. The tactile axis would comprise two conditions: classical massage and supine rest without touch. Each condition would be crossed with a verbal interaction factor at three levels: a body-focused or breathing-oriented conversation, positive directed small talk comparable to the conversational control employed in the present study, and no verbal interaction. This design would allow independent estimation of the contribution of tactile stimulation and of verbal interaction type to observed outcomes, and crucially, would permit assessment of whether verbal content modulates physiological and affective responses differently when combined with touch versus rest alone, thereby isolating the touch-specific regulatory contribution to the MOS reductions and affective patterns documented here. The body-focused conversation condition is theoretically motivated by evidence that interoceptive attention, when verbally guided, activates overlapping insular circuitry to that engaged by CT-afferent stimulation (Mehling et al., 2018), making it a particularly informative comparator for isolating tactile from attentional regulatory pathways. Explicit motivational instructions for the pain tolerance task should be held constant across all conditions to remove the asymmetric motivational confound documented in section 1.3.2. Danner et al. (2025) provide a directly applicable methodological precedent, demonstrating the feasibility of a three-arm RCT comparing full-body slow-stroke massage, active exercise, and a passive lecture control in a healthy Austrian sample, with standardized protocols achieving adequate power to detect between-condition differences on body awareness and mood outcomes.

4.5.2 Expanded Measurement Battery for Future Studies

Physiological markers. Continuous autonomic monitoring via high-frequency heart rate variability (HF-HRV) using a validated chest-strap device such as the Polar H30, in conjunction with wrist-based EDA, would provide a more comprehensive index of parasympathetic engagement and permit direct testing of the CT-afferent pathway model proposed in section 4.2. Including hormonal markers such as salivary oxytocin and cortisol would allow examination of whether attachment-related differences in MOR availability translate into differential opioidergic and HPA-axis responses to structured touch. Moyer et al. (2011), in a meta-analysis of 19 RCTs, found that between-groups effects of massage on cortisol in adults were predominantly small and non-significant, suggesting that salivary oxytocin and sympathetic indices such as EDA may be more sensitive markers of touch-induced regulatory change than cortisol.

Affective and trait measures. The POMS-2 offers subscale-level sensitivity to tension, vigour, and fatigue that the PANAS does not provide, directly addressing the structural limitations detailed in section 4.3.4. The Touch Experiences and Attitudes Questionnaire (TEAQ) would capture trait-level touch preferences and aversion tendencies that are conceptually distinct from attachment dimensions, permitting assessment of whether attitude-level differences in avoidant individuals translate into differential immediate appraisals during the intervention itself (Bowling et al., 2024). The Toronto Alexithymia Scale (TAS-20) would additionally allow assessment of whether difficulties in identifying feelings moderate the attachment-affect associations observed here.

Interoceptive awareness. The Multidimensional Assessment of Interoceptive Awareness (MAIA-2) would enable examination of interoceptive sensitivity as a potential mediator of the bottom-up regulatory pathway proposed in section 4.2. Müller-Oerlinghausen et al. (2022) summarize converging evidence that the antidepressive and anxiolytic effects of slow-stroke massage may be partially mediated through restoration of impaired interoceptive functioning, with the posterior insula serving as the key integration site for CT-afferent input and interoceptive self-representation. This is further supported by Danner et al. (2025), who demonstrated that a single 20-minute full-body massage produced significant increases in body awareness relative to a passive control condition, suggesting that interoceptive body awareness may represent a proximal outcome through which CT-afferent stimulation exerts its downstream regulatory effects.

4.5.3 Neuroimaging Investigation

The pathway-level divergence proposed here between peripheral CT-afferent regulation and central MOR-dependent affective processing can only be assessed through neuroimaging investigation. Structural and functional connectivity analyses using fMRI and diffusion tensor imaging (DTI) would allow examination of whether individual differences in insular cortex thickness, posterior-to-anterior insular connectivity (Björnsdotter et al., 2009), and MOR availability (Nummenmaa et al., 2015) predict the degree to which touch-based interventions modulate stress and affect independent of attachment style. Clinical populations with documented alterations in tactile processing and attachment organization, particularly individuals on the autism spectrum (Kaiser et al., 2016; Failla et al., 2017) and those with fibromyalgia or somatic symptom disorder (Müller-Oerlinghausen et al., 2022), represent theoretically motivated target groups for such investigations.

4.5.4 Standardization in Touch Research and Field Maturation

A broader methodological challenge concerns the limited comparability of findings across the touch research literature. The present study was administered exclusively by a licensed massage therapist with formal training in classical/Swedish techniques, thereby meeting a standard that the broader literature frequently neglects. Yet even within qualified massage therapy, the diversity of schools, traditions, and technical approaches renders cross-study comparability a formidable challenge. Classical massage as practised in the Austrian tradition encompasses a wide spectrum, from fast, light-pressure effleurage to moderate-pressure muscle-specific application to slow, deep-tissue approaches, each of which differentially engages mechanoreceptors and CT-afferents. Traditions such as Traditional Chinese Medicine massage operate along entirely different theoretical and technical frameworks. A field in which the same intervention term encompasses fundamentally non-equivalent interventions has not yet established the baseline necessary for valid comparisons. The present study contributes one controlled, therapist-administered, protocol-standardized data point toward this baseline: a documented effleurage-petrissage sequence of fixed duration, standardized pressure, and specified anatomical coverage. What the field now requires is not fewer studies, but a shared framework for what constitutes comparable touch, that is precise enough to allow results to accumulate rather than cancel, and sensitive enough to distinguish between technique variants that differentially target CT-afferent versus mechanoreceptive input pathways.

4.5.5 Integrative Theoretical Frameworks: From BOTSA to the MASSAG Model

The present study was theoretically grounded in the Brain Opioid Theory of Social Attachment proposed by Machin and Dunbar (2011), which identifies endogenous opioids as the neurochemical substrate linking social touch to affiliative bonding across primate species. This framework provided the mechanistic rationale for expecting attachment-dependent modulation of massage outcomes through differential mu-opioid receptor availability, as directly measured at the neuroimaging level by Nummenmaa et al. (2015). The present findings, while not directly testing opioidergic mediation, are consistent with the predictions of this framework at the behavioural level.

A recent theoretical development that substantially extends this line of reasoning is the MASSAG model proposed by Jinich-Diamant et al. (2026), which offers an integrative neuroscience framework linking force-based manual interventions such as massage to allostatic regulatory gain through simultaneous bottom-up somatosensory pathways, including CT-afferent and deep-pressure signalling, and top-down recalibration of threat-related predictive models in the central nervous system. The model proposes that trauma and chronic stress alter the somatosensory system across six interacting levels, ranging from autonomic and HPA dysregulation to altered skin, fascia, and social processing, and that structured tactile contact addresses these levels concurrently rather than sequentially. The two-pathway divergence documented in the present study, with universal parasympathetic effects alongside attachment-sensitive affective modulation, maps onto this multi-level architecture in a theoretically coherent way. Future empirical work testing the MASSAG model's predictions in attachment-differentiated samples would represent a direct extension of the questions raised here, combining the BOTSA-derived individual difference framework with the somatosensory recalibration mechanisms proposed by Jinich-Diamant and colleagues.

5 References

1. Arnold, M. M., Müller-Oerlinghausen, B., Hemrich, N., & Bönsch, D. (2020). Effects of psychoactive massage in outpatients with depressive disorders: A randomized controlled mixed-methods study. *Brain Sciences*, *10*(10), 676–693. https://doi.org/10.3390/brainsci10100676
2. Aureli, F., Preston, S. D., & De Waal, F. B. M. (1999). Heart rate responses to social interactions in free-moving rhesus macaques (macaca mulatta): A pilot study. *Journal of Comparative Psychology*, *113*(1), 59–65. https://doi.org/10.1037/0735-7036.113.1.59
3. Banissy, M., & Hammond, C. (2020). *The touch test: Attitudes towards and experiences of touch* [Survey Report]. Goldsmiths, University of London, BBC Radio 4, Wellcome Collection. https://www.bbc.co.uk/mediacentre/latestnews/2020/the-touch-test-results
4. Baumgart, S., Müller-Oerlinghausen, B., & Schendera, C. F. G. (2011). Wirksamkeit der massagetherapie bei depression und angsterkrankungen sowie bei depressivität und angst als komorbidität – eine systematische übersicht kontrollierter studien. *Physikalische Medizin, Rehabilitationsmedizin, Kurortmedizin*, *21*(4), 167–182. https://doi.org/10.1055/s-0031-1279760
5. 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. https://doi.org/10.1523/JNEUROSCI.0400-09.2009
6. Boccia, M. L., Reite, M., & Laudenslager, M. (1989). On the physiology of grooming in a pigtail macaque. *Physiology & Behavior*, *45*(3), 667–670. https://doi.org/10.1016/0031-9384(89)90089-9
7. Bohic, M., & Abraira, V. E. (2022). Wired for social touch: The sense that binds us to others. *Current Opinion in Behavioral Sciences*, *43*, 207–215. https://doi.org/10.1016/j.cobeha.2021.10.009
8. Boitor, M., Martorella, G., Arbour, C., Michaud, C., & Gélinas, C. (2015). Evaluation of the preliminary effectiveness of hand massage therapy on postoperative pain of adults in the intensive care unit after cardiac surgery: A pilot randomized controlled trial. *Pain Management Nursing*, *16*(3), 354–366. https://doi.org/10.1016/j.pmn.2014.08.014
9. Boitor, M., Martorella, G., Maheu, C., Laizner, A. M., & Gélinas, C. (2018). Effects of massage in reducing the pain and anxiety of the cardiac surgery critically ill—A randomized controlled trial. *Pain Medicine*, *19*(12), 2556–2569. https://doi.org/10.1093/pm/pny055
10. Bowling, N. C., Vafeiadou, A., Hammond, C., & Banissy, M. J. (2024). Extraversion and adult attachment dimensions predict attitudes towards social touch. *Journal of Research in Personality*, *111*, 104514. https://doi.org/10.1016/j.jrp.2024.104514
11. Breyer, B., & Bluemke, M. (2016). *Deutsche Version der Positive and Negative Affect Schedule PANAS (GESIS Panel). GESIS – Leibniz-Institut für Sozialwissenschaften. https://doi.org/10.6102/zis216*
12. Case, L. K., Madian, N., McCall, M. V., Bradson, M. L., Liljencrantz, J., Goldstein, B., Alasha, V. J., & Zimmerman, M. S. (2023). Aβ-CT affective touch: Touch pleasantness ratings for gentle stroking and deep pressure exhibit dependence on a-fibers. *Eneuro*, *10*(5), ENEURO.0504-22.2023. https://doi.org/10.1523/ENEURO.0504-22.2023
13. Chatel-Goldman, J., Congedo, M., Jutten, C., & Schwartz, J.-L. (2014). Touch increases autonomic coupling between romantic partners. *Frontiers in Behavioral Neuroscience*, *8*. https://doi.org/10.3389/fnbeh.2014.00095
14. Chesler, A. T., Szczot, M., Bharucha-Goebel, D., Čeko, M., Donkervoort, S., Laubacher, C., Hayes, L. H., Alter, K., Zampieri, C., Stanley, C., Innes, A. M., Mah, J. K., Grosmann, C. M., Bradley, N., Nguyen, D., Foley, A. R., Le Pichon, C. E., &

Bönnemann, C. G. (2016). The role of *PIEZO2* in human mechanosensation. *New England Journal of Medicine*, *375*(14), 1355–1364. https://doi.org/10.1056/NEJMoa1602812

15. Chesterton, L. S., Barlas, P., Foster, N. E., Baxter, D. G., & Wright, C. C. (2003). Gender differences in pressure pain threshold in healthy humans. *Pain*, *101*(3), 259–266. https://doi.org/10.1016/S0304-3959(02)00330-5
16. Chopik, W. J., Edelstein, R. S., Van Anders, S. M., Wardecker, B. M., Shipman, E. L., & Samples-Steele, C. R. (2014). Too close for comfort? Adult attachment and cuddling in romantic and parent–child relationships. *Personality and Individual Differences*, *69*, 212–216. https://doi.org/10.1016/j.paid.2014.05.035
17. Coelho, H. F., Boddy, K., & Ernst, E. (2007). Massage therapy for the treatment of depression: A systematic review: MT for the treatment of depression. *International Journal of Clinical Practice*, *62*(2), 325–333. https://doi.org/10.1111/j.1742-1241.2007.01553.x
18. 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. https://doi.org/10.1177/0956797614559284
19. Comte, A., Szymanska, M., Monnin, J., Moulin, T., Nezelof, S., Magnin, E., Jardri, R., & Vulliez-Coady, L. (2024). Neural correlates of distress and comfort in individuals with avoidant, anxious and secure attachment style: An fMRI study. *Attachment and Human Development*, 1–23. https://doi.org/10.1080/14616734.2024.2384393
20. Coste, B., Mathur, J., Schmidt, M., Earley, T. J., Ranade, S., Petrus, M. J., Dubin, A. E., & Patapoutian, A. (2010). Piezo1 and Piezo2 are essential components of distinct mechanically activated cation channels. *Science*, *330*(6000), 55–60. https://doi.org/10.1126/science.1193270
21. Crawford, C., Boyd, C., Paat, C. F., Price, A., Xenakis, L., Yang, E., Zhang, W., & The Evidence For Massage Therapy (Emt) Working Group. (2016). The impact of massage therapy on function in pain populations—a systematic review and meta-analysis of randomized controlled trials: Part I, patients experiencing pain in the general population. *Pain Medicine*, *17*(7), 1353–1375. https://doi.org/10.1093/pm/pnw099
22. Danner, U., Avian, A., & Mittermaier, C. (2025). Massage and exercise increase body awareness in healthy adults: A single blinded randomized controlled trial. *Journal of Bodywork and Movement Therapies*, *45*, 508–515. https://doi.org/10.1016/j.jbmt.2025.08.036
23. De Waal, F. B. M. (1984). *Chimpanzee politics: Power and sex among apes*. Unwin Paperbacks.
24. Ditzen, B., & Heinrichs, M. (2014). Psychobiology of social support: The social dimension of stress buffering. *Restorative Neurology and Neuroscience*, *32*(1), 149–162. https://doi.org/10.3233/RNN-139008
25. Ditzen, B., Neumann, I. D., Bodenmann, G., Von Dawans, B., Turner, R. A., Ehlert, U., & Heinrichs, M. (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. *Psychoneuroendocrinology*, *32*(5), 565–574. https://doi.org/10.1016/j.psyneuen.2007.03.011
26. Dunbar, R. I. M. (1991). Functional significance of social grooming in primates. *Folia Primatologica*, *57*(3), 121–131. https://doi.org/10.1159/000156574
27. Dunbar, R. I. M. (2010). The social role of touch in humans and primates: Behavioural function and neurobiological mechanisms. *Neuroscience & Biobehavioral Reviews, Touch, 34*(2), 260–268. https://doi.org/10.1016/j.neubiorev.2008.07.001
28. Dunbar, R. I. M., Frangou, A., Grainger, F., & Pearce, E. (2021). Laughter influences social bonding but not prosocial generosity to friends and strangers. *PLOS ONE*, *16*(8), e0256229. https://doi.org/10.1371/journal.pone.0256229

29. Ehrenthal, J. C., Dinger, U., Lamla, A., Funken, B., & Schauenburg, H. (2009). Evaluation der deutschsprachigen Version des Bindungsfragebogens „Experiences in Close Relationships – Revised“ (ECR-RD). *Psychotherapie, Psychosomatik, Medizinische Psychologie*, *59(6)*, 215–223. https://doi.org/10.1055/s-0028-1090110
30. Elias, L. J., & Abdus-Saboor, I. (2022). Bridging skin, brain, and behavior to understand pleasurable social touch. *Current Opinion in Neurobiology*, *73*, 102527. https://doi.org/10.1016/j.conb.2022.102527
31. 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. https://doi.org/10.1177/0956797614527114
32. Fang, C.-S., Chang, S.-L., Fang, C.-J., & Chou, F.-H. (2023). Effect of massage therapy on sleep quality in critically ill patients: A systematic review and meta-analysis. *Journal of Clinical Nursing*, *32*(15–16), 4362–4373. https://doi.org/10.1111/jocn.16660
33. Farber, K., & Wieland, L. S. (2016). Massage for low-back pain. *Explore*, *12*(3), 215–217. https://doi.org/10.1016/j.explore.2016.02.014
34. Field, T. (2019). Social touch, CT touch and massage therapy: A narrative review. *Developmental Review*, *51*, 123–145. https://doi.org/10.1016/j.dr.2019.01.002
35. Field, T., Hernandez-Reif, M., Diego, M., Schanberg, S., & Kuhn, C. (2005). Cortisol decreases and serotonin and dopamine increase following massage therapy. *International Journal of Neuroscience*, *115*(10), 1397–1413. https://doi.org/10.1080/00207450590956459
36. Fraley, R. C. (2012). *Information on the Experiences in Close Relationships-Revised (ECR-R) Adult Attachment Questionnaire*. University of Illinois at Urbana-Champaign. Retrieved May 2026, from https://labs.psychology.illinois.edu/~rcfraley/measures/ecrr.htm
37. Fraley, R. C., Waller, N. G., & Brennan, K. A. (2000). An item response theory analysis of self-report measures of adult attachment. *Journal of Personality and Social Psychology*, *78*(2), 350–365. https://doi.org/10.1037/0022-3514.78.2.350
38. Gothard, K. M., & Fuglevand, A. J. (2022). The role of the amygdala in processing social and affective touch. *Current Opinion in Behavioral Sciences*, *43*, 46–53. https://doi.org/10.1016/j.cobeha.2021.08.004
39. 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. https://doi.org/10.1016/j.brainres.2014.02.002
40. Habig, K., Schänzer, A., Schirner, W., Lautenschläger, G., Dassinger, B., Olausson, H., Birklein, F., Gizewski, E. R., & Krämer, H. H. (2017). Low threshold unmyelinated mechanoafferents can modulate pain. *BMC Neurology*, *17*(1), 184–194. https://doi.org/10.1186/s12883-017-0963-6
41. 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. *Journal of Clinical Psychiatry*, *71*(7), 894–901. https://doi.org/10.4088/JCP.09r05009blu
42. Huzard, D., Martin, M., Maingret, F., Chemin, J., Jeanneteau, F., Mery, P.-F., Fossat, P., Bourinet, E., & François, A. (2022). The impact of C-tactile low-threshold mechanoreceptors on affective touch and social interactions in mice. *Science Advances*, 1–16. https://doi.org/10.1126/sciadv.abo7566
43. IBM Corp. (2022). *IBM SPSS Statistics for Windows* (Version 29.0.0) [Computer software]. IBM Corp. https://www.ibm.com/products/spss-statistics
44. Jinich-Diamant, A., Albinni, B., Fishbein, J. N., Jacobson, E., Abraira, V. E., Hong, S., Korgan, A. C., Mazzieri, A.-M., & Case, L. (2026). MASSAG model: Towards an integrative neuroscience framework linking emotional trauma, pain, and mechanisms of

force-based manipulations. *Neuroscience & Biobehavioral Reviews*, *181*, 106517. https://doi.org/10.1016/j.neubiorev.2025.106517
45. Johnson, K. V.-A., & Dunbar, R. I. M. (2016). Pain tolerance predicts human social network size. *Scientific Reports*, *6*(1), 25267. https://doi.org/10.1038/srep25267
46. Kandeel, N. A., El-Hady, M. M., & Tantawy, N. (2019). The effect of back massage on perceived sleep quality among adult patients in intensive care units. *Egyptian Journal of Health Care,* 10 (3), 278–285.
47. Keverne, E. B., Martensz, N. D., & Tuite, B. (1989). Beta-endorphin concentrations in cerebrospinal fluid of monkeys are influenced by grooming relationships. *Psychoneuroendocrinology*, *14*(1–2), 155–161. https://doi.org/10.1016/0306-4530(89)90065-6
48. Knight, K., & Napier, E. (2020). Immediate effects of prophylactic therapeutic massage on pain tolerance and threshold. *Manual Therapy, Posturology & Rehabilitation Journal*, *18*, 1–5. https://doi.org/10.17784/mtprehabjournal.2020.18.1186
49. Krahé, C., Drabek, M. M., Paloyelis, Y., & Fotopoulou, A. (2016). Affective touch and attachment style modulate pain: A laser-evoked potentials study. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1708), 20160009. https://doi.org/10.1098/rstb.2016.0009
50. Krahé, C., Paloyelis, Y., Condon, H., Jenkinson, P. M., Williams, S. C. R., & Fotopoulou, A. (2015). Attachment style moderates partner presence effects on pain: A laser-evoked potentials study. *Social Cognitive and Affective Neuroscience*, *10*(8), 1030–1037. https://doi.org/10.1093/scan/nsu156
51. Krahé, C., Von Mohr, M., Gentsch, A., Guy, L., Vari, C., Nolte, T., & Fotopoulou, A. (2018). Sensitivity to CT-optimal, affective touch depends on adult attachment style. *Scientific Reports*, *8*(1), 14544. https://doi.org/10.1038/s41598-018-32865-6
52. Kyriakou, K., Resch, B., Sagl, G., Petutschnig, A., Werner, C., Niederseer, D., Liedlgruber, M., Wilhelm, F., Osborne, T., & Pykett, J. (2019). Detecting moments of stress from measurements of wearable physiological sensors. *Sensors*, *19*(17), 3805. https://doi.org/10.3390/s19173805
53. Liljencrantz, J., Strigo, I., Ellingsen, D. M., Krämer, H. H., Lundblad, L. C., Nagi, S. S., Leknes, S., & Olausson, H. (2017). Slow brushing reduces heat pain in humans. *European Journal of Pain*, *21*(7), 1173–1185. https://doi.org/10.1002/ejp.1018
54. Machin, A. J., & Dunbar, R. I. M. (2011). The brain opioid theory of social attachment: A review of the evidence. *Behaviour*, *148*(9–10), 985–1025. https://doi.org/10.1163/000579511X596624
55. Madden, J. R., & Clutton-Brock, T. H. (2009). Madden, Joah R., und Tim H. Clutton-Brock. „Manipulating Grooming by Decreasing Ectoparasite Load Causes Unpredicted Changes in Antagonism“. *Proceedings of the Royal Society B: Biological Sciences* 276, Nr. 1660 (2009): 1263–68. https://doi.org/10.1098/rspb.2008.1661.
56. McGlone, F., Uvnäs Moberg, K., Norholt, H., Eggart, M., & Müller-Oerlinghausen, B. (2024). Touch medicine: Bridging the gap between recent insights from touch research and clinical medicine and its special significance for the treatment of affective disorders. *Frontiers in Psychiatry*, *15*, 1390673. https://doi.org/10.3389/fpsyt.2024.1390673
57. McGlone, F., Wessberg, J., & Olausson, H. (2014). Discriminative and affective touch: Sensing and feeling. *Neuron*, *82*(4), 737–755. https://doi.org/10.1016/j.neuron.2014.05.001
58. Meier, M., Unternaehrer, E., Dimitroff, S. J., Benz, A. B. E., Bentele, U. U., Schorpp, S. M., Wenzel, M., & Pruessner, J. C. (2020). Standardized massage interventions as protocols for the induction of psychophysiological relaxation in the laboratory: A block randomized, controlled trial. *Scientific Reports*, *10*(1), 14774. https://doi.org/10.1038/s41598-020-71173-w

59. Menghini, L., Gianfranchi, E., Cellini, N., Patron, E., Tagliabue, M., & Sarlo, M. (2019). Stressing the accuracy: Wrist-worn wearable sensor validation over different conditions. *Psychophysiology*, *56*(11), e13441. https://doi.org/10.1111/psyp.13441
60. Meredith, P. J. (2013). A review of the evidence regarding associations between attachment theory and experimentally induced pain. *Current Pain and Headache Reports*, *17*(4), 326–334. https://doi.org/10.1007/s11916-013-0326-y
61. Microsoft Corporation. (2025). *Microsoft Excel for Microsoft 365* (Versions 2602) [Computer software]. https://www.microsoft.com/excel
62. Moyer, C. A., Seefeldt, L., Mann, E. S., & Jackley, L. M. (2011). Does massage therapy reduce cortisol? A comprehensive quantitative review. *Journal of Bodywork and Movement Therapies*, *15*(1), 3–14. https://doi.org/10.1016/j.jbmt.2010.06.001
63. Navarro, Danielle J. (2015). *Learning statistics with R: A tutorial for psychology students and other beginners*. https://learningstatisticswithr.com
64. Nummenmaa, L., Manninen, S., Tuominen, L., Hirvonen, J., Kalliokoski, K. K., Nuutila, P., Jääskeläinen, I. P., Hari, R., Dunbar, R. I. M., & Sams, M. (2015). Adult attachment style is associated with cerebral μ-opioid receptor availability in humans: Opioids and attachment. *Human Brain Mapping*, *36*(9), 3621–3628. https://doi.org/10.1002/hbm.22866
65. Nummenmaa, L., Tuominen, L., Dunbar, R., Hirvonen, J., Manninen, S., Arponen, E., Machin, A., Hari, R., Jääskeläinen, I. P., & Sams, M. (2016). Social touch modulates endogenous μ-opioid system activity in humans. *Neuroimage*, *138*, 242–247. https://doi.org/10.1016/j.neuroimage.2016.05.063
66. Nunes, G. S., Bender, P. U., De Menezes, F. S., Yamashitafuji, I., Vargas, V. Z., & Wageck, B. (2016). Massage therapy decreases pain and perceived fatigue after long-distance ironman triathlon: A randomised trial. *Journal of Physiotherapy*, *62*(2), 83–87. https://doi.org/10.1016/j.jphys.2016.02.009
67. Olausson, H., Wessberg, J., Morrison, I., McGlone, F., & Vallbo, Å. (2010). The neurophysiology of unmyelinated tactile afferents. *Neuroscience & Biobehavioral Reviews*, *34*(2), 185–191. https://doi.org/10.1016/j.neubiorev.2008.09.011
68. Ollander, S., Godin, C., Campagne, A., & Charbonnier, S. (2016). A comparison of wearable and stationary sensors for stress detection. *2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, 004362–004366. https://doi.org/10.1109/SMC.2016.7844917
69. Packheiser, J., Hartmann, H., Fredriksen, K., Gazzola, V., Keysers, C., & Michon, F. (2024). 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
70. Pawling, R., Cannon, P. R., McGlone, F. P., & Walker, S. C. (2017). C-tactile afferent stimulating touch carries a positive affective value. *PLOS One*, *12*(3), e0173457. https://doi.org/10.1371/journal.pone.0173457
71. Pearce, E., Wlodarski, R., Machin, A., & Dunbar, R. I. M. (2017). Variation in the β-endorphin, oxytocin, and dopamine receptor genes is associated with different dimensions of human sociality. *Proceedings of the National Academy of Sciences*, *114*(20), 5300–5305. https://doi.org/10.1073/pnas.1700712114
72. Pérez Pérez, A., & Veà, J. J. (2000). Allogrooming behavior inCercocebus torquatus: The case for the hygienic functional hypothesis. *Primates*, *41*(2), 199–207. https://doi.org/10.1007/BF02557801
73. Posit Team. (2025). *RStudio* (Version 2024.12.1+563 'Kousa Dogwood') [Computer software]. https://posit.co/
74. Powell, H., He, J., Magnani, K., Hu, K., Barnes, L., Beßler, R., Chib, V. S., & Puts, N. (2024). *Decoding social touch: A multi-modal exploration of tactile perception, gender and culture* [Preprint]. PsyArXiv. https://doi.org/10.31234/osf.io/cy4b5

75. Qiu, J., Jiang, Y., Li, F., Tong, Q., Rong, H., & Cheng, R. (2017). Effect of combined music and touch intervention on pain response and β-endorphin and cortisol concentrations in late preterm infants. *BMC Pediatrics*, *17*(1), 38–45. https://doi.org/10.1186/s12887-016-0755-y
76. Rapaport, M. H., Schettler, P., Larson, E. R., Edwards, S. A., Dunlop, B. W., Rakofsky, J. J., & Kinkead, B. (2016). Acute swedish massage monotherapy successfully remediates symptoms of generalized anxiety disorder: A proof-of-concept, randomized controlled study. *Journal of Clinical Psychiatry*, *77*(7), e883–e891. https://doi.org/10.4088/JCP.15m10151
77. Revelle, W. (2025). *psych: Procedures for psychological, psychometric, and personality research* (Version 2.5.3) [Computer software]. https://personality-project.org/r/psych
78. Romeo, A., Tesio, V., Castelnuovo, G., & Castelli, L. (2017). Attachment style and chronic pain: Toward an interpersonal model of pain. *Frontiers in Psychology*, *8*, 1–6. https://doi.org/10.3389/fpsyg.2017.00284
79. Sable, A., Sivabalan, T., & Shetti, A. (2017). Effectiveness of back massage on sleep pattern among patients with congestive cardiac failure. *Iranian Journal of Nursing and Midwifery Research*, *22*(5), 359–362. https://doi.org/10.4103/ijnmr.IJNMR_142_16
80. Sánchez López de Nava, A., & Raja, A. (2026). Physiology, metabolism. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK546690/
81. Schino, G., Scucchi, S., Maestripieri, D., & Turillazzi, P. G. (1988). Allogrooming as a tension-reduction mechanism: A behavioral approach. *American Journal of Primatology*, *16*(1), 43–50. https://doi.org/10.1002/ajp.1350160106
82. Sherman, K. J., Ludman, E. J., Cook, A. J., Hawkes, R. J., Roy-Byrne, P. P., Bentley, S., Brooks, M. Z., & Cherkin, D. C. (2010). Effectiveness of therapeutic massage for generalized anxiety disorder: A randomized controlled trial. *Depression and Anxiety*, *27*(5), 441–450. https://doi.org/10.1002/da.20671
83. Sumioka, H., Nakae, A., Kanai, R., & Ishiguro, H. (2013). Huggable communication medium decreases cortisol levels. *Scientific Reports*, *3*(1), 3034. https://doi.org/10.1038/srep03034
84. Takano, T., & Mogi, K. (2019). Adult attachment style and lateral preferences in physical proximity. *Biosystems*, *181*, 88–94. https://doi.org/10.1016/j.biosystems.2019.05.002
85. Tammilehto, J., Kuppens, P., Bosmans, G., Flykt, M., Peltonen, K., Vänskä, M., & Lindblom, J. (2023). Attachment orientation and dynamics of negative and positive emotions in daily life. *Journal of Research in Personality*, *105*, 104398. https://doi.org/10.1016/j.jrp.2023.104398
86. Tarr, B., Launay, J., Cohen, E., & Dunbar, R. (2015). Synchrony and exertion during dance independently raise pain threshold and encourage social bonding. *Biology Letters*, *11*(10), 20150767. https://doi.org/10.1098/rsbl.2015.0767
87. The Nobel Assembly at Karolinska Institutet. (2021). *The Nobel Prize in Physiology or Medicine 2021: Scientific Background – Discoveries of Receptors for Temperature and Touch* [Scientific Background Document]. NobelPrize.org. https://www.nobelprize.org/prizes/medicine/2021/advanced-information/
88. Torchiano, M. (2016). *Effsize—A package for efficient effect size computation* [Computer software]. Zenodo. https://doi.org/10.5281/ZENODO.1480624
89. 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. https://doi.org/10.1016/j.biopsycho.2017.07.007
90. Tucker, J. S., & Anders, S. L. (1998). Adult attachment style and nonverbal closeness in dating couples. *Journal of Nonverbal Behavior*, 22 (2), 109–124.
91. Turtonen, O., Saarinen, A., Nummenmaa, L., Tuominen, L., Tikka, M., Armio, R.-L., Hautamäki, A., Laurikainen, H., Raitakari, O., Keltikangas-Järvinen, L., & Hietala, J.

(2021). Adult attachment system links with brain mu opioid receptor availability In vivo. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *6*(3), 360–369. https://doi.org/10.1016/j.bpsc.2020.10.013
92. Van Dooren, M., De Vries, J. J. G., & Janssen, J. H. (2012). Emotional sweating across the body: Comparing 16 different skin conductance measurement locations. *Physiology & Behavior*, *106*(2), 298–304. https://doi.org/10.1016/j.physbeh.2012.01.020
93. Von Au, S., Marsh, N., Jeske, V., Hurlemann, R., & Lausberg, H. (2025). Effects of self-touch and social-touch on peripheral oxytocin concentrations: A study conducted during the COVID-19 pandemic. *Physiology & Behavior*, *301*, 115061. https://doi.org/10.1016/j.physbeh.2025.115061
94. Von Mohr, M., Crowley, M. J., Walthall, J., Mayes, L. C., Pelphrey, K. A., & Rutherford, H. J. V. (2018). EEG captures affective touch: CT-optimal touch and neural oscillations. *Cognitive, Affective and Behavioral Neuroscience*, *18*(1), 155–166. https://doi.org/10.3758/s13415-017-0560-6
95. Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

6 Acknowledgements

The author would like to thank Elisabeth Oberzaucher and Kathrin Masuch for their continuous support throughout this project. Gratitude is extended to Dominik Siedlacek for providing the research space, and to Robin Dunbar for his correspondence and helpful input. Thanks are also due to the Berührungsmedizinische Gesellschaft for their assistance with literature, and to Theresa Stürmer for her collaboration on the conversational protocol. The author further thanks the Vienna University of Technology for providing the physiological measurement equipment, and Linda Dörrzapf and Martin Moser for their support with the Moments of Stress methodology. Christina Raffelsberger is thanked for her assistance with data analysis. Finally, the author is grateful to Peter Gauß for his advice and support throughout the entire research process.

7 Appendix

Figure A1. Recruitment flyer distributed on university campuses and via online channels to advertise the study and invite eligible participants to complete the initial screening questionnaire.

Themenauswahl

Lies dir die folgenden Themen durch und wähle eines oder mehrere aus! Ziel ist ein lockeres Gespräch für die Dauer von ca. 30 Minuten. Der Inhalt dieses Gesprächs ist für uns nicht relevant.

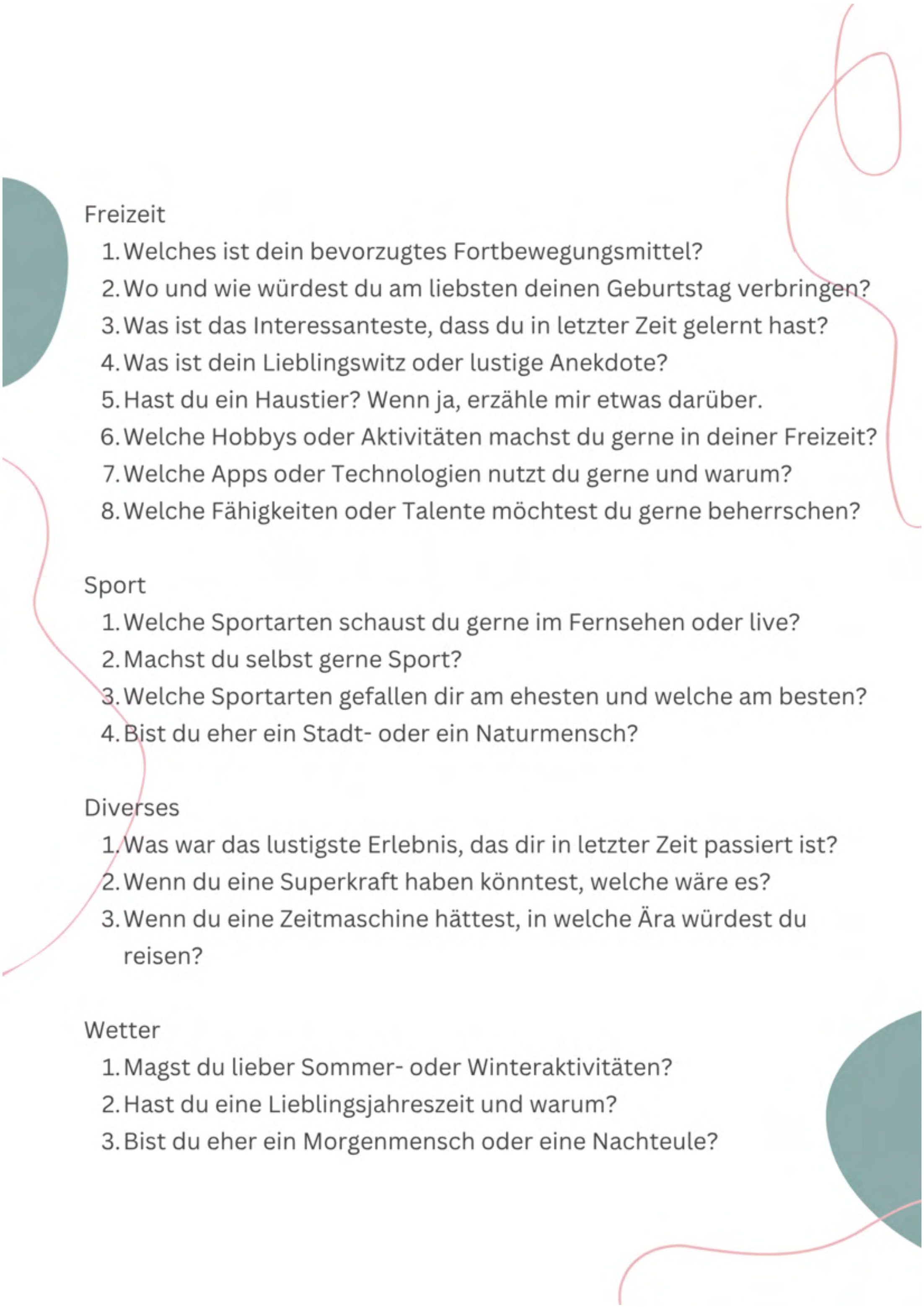
Kultur

1. Was war das letzte Buch, das du gelesen hast, und hat es dir gefallen?
2. Hast du eine Lieblingsserie oder einen Lieblingsfilm? Was gefällt dir daran?
3. Welche Art von Filmen oder Büchern magst du überhaupt nicht?
4. Welche Art von Musik hörst du am liebsten? Hast du einen Lieblingssong?
5. Was ist dein Lieblingsessen oder deine Lieblingsküche?
6. Was war das beste Konzert oder die beste Live-Veranstaltung, die du besucht hast?
7. Was war das beeindruckendste Museum oder die beeindruckendste Ausstellung, die du besucht hast?
8. Was ist dein Lieblingszitat oder Lebensmotto?
9. Welche Art von Veranstaltungen oder Partys magst du am liebsten?

Reisen

1. Welche Reiseziele stehen auf deiner Wunschliste? Warum interessieren sie dich?
2. Welche Sprachen würdest du gerne beherrschen und warum?
3. Erzähl uns von deinem letzten Urlaub!
4. Bist du schon mal alleine verreist? Wie war die Erfahrung für dich?

Figure A2. Conversation topic protocol used in the control condition, Page 1. The semi-structured topic list provided a standardized menu of neutral subjects to ensure consistency across all control sessions while maintaining a naturalistic social interaction.



Freizeit

1. Welches ist dein bevorzugtes Fortbewegungsmittel?
2. Wo und wie würdest du am liebsten deinen Geburtstag verbringen?
3. Was ist das Interessanteste, dass du in letzter Zeit gelernt hast?
4. Was ist dein Lieblingswitz oder lustige Anekdote?
5. Hast du ein Haustier? Wenn ja, erzähle mir etwas darüber.
6. Welche Hobbys oder Aktivitäten machst du gerne in deiner Freizeit?
7. Welche Apps oder Technologien nutzt du gerne und warum?
8. Welche Fähigkeiten oder Talente möchtest du gerne beherrschen?

Sport

1. Welche Sportarten schaust du gerne im Fernsehen oder live?
2. Machst du selbst gerne Sport?
3. Welche Sportarten gefallen dir am ehesten und welche am besten?
4. Bist du eher ein Stadt- oder ein Naturmensch?

Diverses

1. Was war das lustigste Erlebnis, das dir in letzter Zeit passiert ist?
2. Wenn du eine Superkraft haben könntest, welche wäre es?
3. Wenn du eine Zeitmaschine hättest, in welche Ära würdest du reisen?

Wetter

1. Magst du lieber Sommer- oder Winteraktivitäten?
2. Hast du eine Lieblingsjahreszeit und warum?
3. Bist du eher ein Morgenmensch oder eine Nachteule?

Figure A3 Conversation topic protocol used in the control condition, Page 2. Topics were selected by participants from the provided list; emotionally charged or stressful subjects were excluded from the protocol.