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Affective touch and regulation of stress responses

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ABSTRACT

Much has been documented on the association between stress and health. Both direct and indirect pathways have been identified and explored extensively, helping us understand trajectories from healthy individuals to reductions in well-being, and development of preclinical and disease states. Some of these pathways are well established within the field; physiology, affect regulation, and social relationships. The purpose of this review is to push beyond what is known separately about these pathways and provide a means to integrate them using one common mechanism. We propose that social touch, specifically affective touch, may be the missing active ingredient fundamental to our understanding of *how* close relationships contribute to stress and health. We provide empirical evidence detailing how affective touch is fundamental to the development of our stress systems, critical to the development of attachment bonds and subsequent social relationships across the life course. We will also explore how we can use this in applied contexts and incorporate it into existing interventions.

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Introduction

Over the past forty years, health psychologists have focused on understanding *why* close relationships may offer protection against the deleterious effects of stress on health and well-being (Kidd, 2016; O'Connor et al., 2021). We know much less about *how* close relationships offer protection against stress and negative health outcomes. One reason for this may be that health psychologists often employ a 'top down' approach to understanding behaviour; however, in this narrative review, we aim to integrate a 'bottom up' approach, incorporating social neuroscience research on affective touch, to propose a multidisciplinary perspective that may enable us to begin to answer this critically important question and consider how we can incorporate this in practice.

What we know

There is unequivocal evidence that stress is associated with poor health outcomes (O'Connor et al., 2021; Segerstrom & O'Connor, 2012), and that close supportive relationships enhance health and well-being, while poor quality relationships can be precipitating factors in the development of affective disorders and physical health conditions (Holt-Lunstad, 2018; Stanton et al., 2019; Walker & McGlone, 2013). There is a strong link between our social relationships and psychophysiological responses to stress (Davidson & Mcewen, 2012; Farrell & Stanton, 2019; Pietromonaco & Beck, 2019), suggesting that supportive social relationships may buffer us from the health damaging effects of stress (Cohen & McKay, 2020).

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In healthy humans, the ability of neural networks to change and reorganise synaptic connections begins in the third trimester, where there is a rapid neural proliferation. Synaptic connections are formed, strengthened, and maintained when two neurons are repeatedly co-activated during this critical period (Johnston, 1995; Tierney & Nelson, 2009). For example, synaptic connections in the hippocampus, medial prefrontal cortex and amygdala are activated and strengthened during threat (McEwen et al., 2016; Morin et al., 2020; Tottenham, 2020). These brain regions are (1) responsible for emotion processing, (2) known to be highly sensitive to psychosocial stress and (3) abundant with glucocorticoid receptors (Lupien et al., 2009), making them key players in the regulation of stress response systems such as the hypothalamic–adrenal–pituitary HPA axis (McEwen, 2007; Teicher et al., 2003; Walker et al., 2001).

Activation of the HPA axis leads to the release of corticotropin releasing factor (CRF) and vasopressin into the anterior pituitary, stimulating the release of adrenocorticotropin (ACTH), which then triggers the adrenal cortex to release the glucocorticoid, cortisol. While the acute release of cortisol is incredibly adaptive in the short term, the ability to 'switch off' the stress system and return the body back to a homeostatic state is equally crucial (McEwen, 1998). The hippocampus, with its abundance of glucocorticoid receptors enabling the detection of a wide range of circulating glucocorticoids, plays a key role in inhibiting the release of CRF, and 'switching off' the HPA axis.

Evidence suggests that it is our earliest experience of close relationships, namely between an infant and caregiver, that is crucial in the development of brain regions associated with stress system development and regulation (Cohodes et al., 2021; Lee et al., 2018; McEwen, 2011; Smith & Pollak, 2020). Adverse early life experiences can have profound effects on developing nervous, endocrine, and immune systems (Engel & Gunnar, 2020; Merz & Turner, 2021). Research has shown that early life stress is associated with structural changes in the hippocampus and amygdala, these include dendritic debranching of neurons, synaptic remodelling, and hypertrophy (McEwen, 2003). This impact on neural plasticity results in lower numbers of these crucial glucocorticoid and mineralocorticoid receptors in the hippocampus (Daskalakis et al., 2015; Rao et al., 2010; Von Werne Baes et al., 2012). It is for this reason the HPA axis is often the stress system of choice for researchers interested in interpersonal relationships because (1) care received during early developmental periods can have lasting effects on HPA function and stress responsivity (Meaney, 2001), (2) it is activated during socio-evaluative threat (Dickerson & Kemeny, 2004).

It should be noted that the term early life adversity covers a diverse range of circumstances and so it is important to consider the timing, quantity and nature of adverse experience when evaluating current and/or future neural development (Bosch et al., 2012; Nelson & Gabard-Durnam, 2020). Children may be exposed to multiple forms of adversity that persist into young adulthood and range in severity; for example, poverty, lack of parental warmth, physical or sexual abuse (Felitti et al., 1998; Kessler et al., 2010; Taylor, 2010). While research has focused on formative 'critical' periods in early life it is worth highlighting that synaptic pruning continues through adolescence into young adulthood, and cumulative risk exposure may lead to strengthening neurological reconfiguration in the brain associated with threat (Engel & Gunnar, 2020; Kim et al., 2013; Nusslock & Miller, 2016); whereby biological responses may be up or down regulated resulting in dysregulation of stress system response and disease development over time (Carpenter et al., 2009; Heim et al., 2000; Lupien et al., 2009). This is supported by research on adverse early life experiences predicting future adult neurobiological, metabolic, and immune changes (Berens et al., 2017; Elwenspoek et al., 2017; Fagundes et al., 2013; Goldman-Mellor et al., 2012; Young et al., 2021). Additionally, dysregulation in these systems from an early age may confer an increased risk of developing physical health conditions, such as cardiovascular disease in adult life, over and above the norms expected in stressed adults (Eriksson et al., 2014; Friedman et al., 2015; Kivimäki & Steptoe, 2018; Miller et al., 2011).

Attachment theory, an indicator of social relationship quality, has been applied as a framework to understand how early life experience may contribute to biological and psychological stress responsivity across the life course (Kidd et al., 2011, 2013; Maunder & Hunter, 2001; Pietromonaco & Beck, 2019). A tenet of attachment theory is that humans are born with a basic need for social connection that serves the evolutionary function of ensuring survival of the infant (Bowlby, 1969). This means that attachment is an adaptive process, and attachment strategies are developed in response to the early social environment and care experienced during times of distress (Fonagy, 2001; Granqvist et al., 2017). The attachment system is activated during times of (1) threat to self (e.g., hunger, pain, illness), (2) environmental threat (e.g., frightening or dangerous situations), and (3) relationship threat (e.g., loss of proximity, conflict).

When the attachment system becomes activated the caregiver acts as an external regulator of emotional arousal and physiological regulation for the infant during the threat. Schemas (internal working models of memory) are developed based on repeated interactions with caregivers and the care received during times of distress. These internal working models detail expectations related to future threat, strategies to express or inhibit emotions, as well as initiating a physiological response to a perceived threat (Bowlby, 1969). Internal working models, therefore, form the basis of attachment orientation and help us understand variation in stress reactivity and regulation (Pietromonaco et al., 2006). What is unique about attachment behaviour is that it is relatively stable, and internal working models are maintained into adulthood (Fraley et al., 2011; Hazan & Shaver, 1987).

Secure attachment orientations reflect positive expectations that the caregiver will be available and responsive; whereas infants who receive inconsistent (anxious attachment) or nonresponsive care (avoidant attachment) do not have a sense of safety or security, and they are often referred to as insecure attachments. Individuals with insecure attachment develop secondary strategies to minimise distress (Sroufe & Waters, 1977). These strategies include hypervigilance to threat, and deactivation/autonomy respectively (Brennan et al., 1998). There is a third category of attachment that falls outside the previously described organised strategies, where attachment goals to reduce distress are unresolved. Disorganised (fearful) attachment reflects high levels of both attachment anxiety and avoidance and is characterised by competing hyperactivating (approach) and deactivating (avoid) strategies. If attachment needs are not met, the attachment system remains activated (Kidd et al., 2013).

Evidence that attachment modulates physiological stress responses and is associated with early patterns of dysregulation comes from studies of insecurely attached infants and children (Gunnar et al., 1996). Cortisol has a circadian pattern that typically emerges in the first few months of life, that remains relatively stable across the life course (Larson et al., 1998; Price et al., 1983) and dysregulation of the diurnal profile is indicative of HPA dysregulation in insecure infants and children (Luijk et al., 2010; Oskis et al., 2011). Insecure attachment has also been associated with both heightened and blunted cortisol responses to an acute stressor, often measured using the strange situation, where infants are separated before being reunited with their primary caregiver (Bernard & Dozier, 2010; Spangler & Grossmann, 1993). At the other end of the chronological spectrum, insecure attachment has consistently been associated with both heightened and blunted physiological responses to stress across a variety of naturalistic, inter and intra-experimental contexts in adults (Jaremka et al., 2013; Kidd, 2016; Kidd et al., 2011, 2013; Powers et al., 2006). It is believed that some of these differences may be linked to the hormone oxytocin, a hypothalamic neuropeptide, associated with neurophysiological mechanism underlying social relationships, which may play a pivotal role linking attachment with HPA axis reactivity (Feldman, 2017). Importantly, these patterns of hyper and hypo response are characteristic of the allostatic load model, often used to explain early emergence of diseases associated with aging, the 'wear and tear' of the stress systems associated with development and progression of disease across the life course (McEwen, 1998).

There is growing evidence that attachment orientation may be implicated in alterations in neural circuits and networks that are associated with self-regulation and changes to brain structure that support this (Long et al., 2020; Oliveira & Fearon, 2019; Perlini et al., 2019). Attachment strategies may modulate stress systems, such as the HPA axis through these alterations (Teicher et al., 2003). Specifically, insecure attachment has been related to changes in the hippocampus and amygdala in children and adolescents (Lupien et al., 2011); however, findings have been mixed with both hippocampal and amygdala volume increases and decreases found (Cortes Hidalgo et al., 2019; Lyons-

Ruth et al., 2016; Rifkin-Graboi et al., 2019; van Hoof et al., 2019). Some disparity may be due to the focus on disorganised attachment, the use of clinical populations, age of the sample, and developmental period (Oliveira & Fearon, 2019).

Similarly, mixed findings have been reported for adults, where some studies suggest that insecure attachment may be a risk factor for grey matter reduction in brain regions associated with emotion processing; specifically, attachment avoidance has been associated with bilateral hippocampal reduction, and attachment anxiety related to reduced cell concentration in the left hippocampus (Quirin et al., 2010; Zhang et al., 2018). These changes are believed to be caused by excess glucocorticoid levels and glucocorticoid receptor downregulation in the hippocampus generating a feed-forward cascade of degeneration and disease (Oitzl et al., 2010; Sapolsky et al., 2002). In contrast, Moutsiana and colleagues examined hippocampal and amygdala volume in adults whose attachment style had been observed 22years previously (aged 18 months). Upon examining insecure vs secure attachment, they found increased amygdala but not hippocampal volume (Moutsiana et al., 2015). Despite mixed reports, these finding do provide support for the proposition that insecure attachment increases experience of chronic stress, increasing allostatic load, resulting in dysregulation and structural alterations of stress systems in the brain (Katz et al., 2012; Kidd, 2016; Kidd et al., 2013, 2014; Pietromonaco & Beck, 2019; Quirin et al., 2010).

What we need to know

Importantly, while attachment research has furthered our understanding of differences in stress responsivity, several missing pieces of the puzzle remain. Firstly, there is a lack of specificity regarding the mechanisms of action that are responsible for regulating affect, arousal and physiological regulation within the infant and caregiver dyad. What underlies secure attachment that buffers stress and promotes resilience? Second, how can we use that information to develop evidence-based interventions to promote stress resilience and healthy lives?

The remainder of this review will focus on direct and indirect evidence that a specific type of affiliative touch, referred to in the field of social neuroscience as affective touch, is necessary and vital for promoting attachment security and stress resilience (Fotopoulou et al., 2022; Morrison, 2016b; Walker & McGlone, 2013). In the following sections we will detail the regulatory mechanisms and pathways that confer resilience and are associated with positive health outcomes. Then to finish we will consider how further understanding of the neurobiological basis of the stress buffering effects of affiliative touch can aid the development of interventions.

Why touch?

Motivation to seek comfort from others is innate and leads to the early establishment of protective attachment relationships (Bowlby, 1982; Harlow, 1958). Correspondingly, touch is the first sensation to develop in the embryo, the last to fade in old age (McGrath, 2009), and has lifelong benefits on endocrine and autonomic nervous system reactivity to stressors (Fotopoulou et al., 2022). Importantly, touch is a key sensory channel for parental-infant interactions and is believed to account for 70% of all communication within the dyad (Hofer, 1994; Montirosso & McGlone, 2020; Walker et al., 2017a).

A range of studies report that early nurturing tactile interaction is associated with reduced stress-responsive neuroendocrine systems in humans and non-human mammals (Carozza & Leong, 2021; Meaney, 2001; Van Puyvelde et al., 2019a, 2019b; Walker et al., 2017a). For example, skin-to-skin contact has demonstrable clinical benefits for premature infants (El-Farrash et al., 2020). A brief, daily tactile intervention delivering short bouts of stroking, passive limb flexion and extension leads to more rapid physical growth, reduced stress related behaviours and enhanced neuroendocrine and cognitive development in preterm infant (Field et al., 1986; Kuhn et al., 1991). Acutely too, affiliative social behaviours, involving tactile interactions, exert stress-attenuating effects. For example, infants who are touched during a typically distressing social interaction – the still-face paradigm – cried less than infants who were not touched (Lowe et al., 2016; Stack & Muir, 1990; Williams & Turner, 2020).

In adults, supportive physical contact from a spouse or partner has been shown to modulate physiological and neural responses to an acutely stressful event (Coan et al., 2006; Holt-Lunstad et al., 2008). Physiologically, women receiving physical comfort from their partner prior to an acute stress challenge displayed significantly lower salivary cortisol levels and significantly smaller increases in heart rate than women who were alone. In contrast, purely verbal support did not buffer stress reactivity in a laboratory-based study (Ditzen et al., 2007). Thus, physical contact may play an important role in the stress buffering benefits of social support.

What is affective touch and why it is important in the development of stress systems?

The skin of the body is innervated by a system of nerves which convey signals from the skin surface to the brain. The sense of touch is typically considered with respect to its discriminative, exteroceptive functions, supporting the haptic exploration and manipulation of objects, and detection of external stimuli on the body surface (McGlone & Reilly, 2010). However, it has recently come to be recognised that touch can also be emotional and interoceptive – consider the feeling of reassurance provided by a gentle touch on the back, or the pleasure of a loving caress (McGlone et al., 2014). Two different classes of nerve fibre mediate these dissociable aspects of touch. Large, myelinated A-beta afferents provide rapid information about the location of skin contact, whereas the identification and functional characterisation of an unmyelinated, slow conducting C type fibre, which responds optimally to gentle stroking touch provides a neurobiological target for investigating the well-recognised, protective benefits of nurturing tactile interactions. These so called, c-tactile afferents (CTs) are velocity and temperature tuned. They respond optimally to a skin temperature stimulus moving across their receptive field at between 1 and 10 cm/s. They are less responsive to faster and slower, warmer and cooler stimuli. Intriguingly, there is a positive correlation between the firing frequency of CTs and people's ratings of touch pleasantness (Ackerley et al., 2014; Löken et al., 2009; Olausson et al., 2010). Neurally, while discriminative touch fibres project to primary somatosensory cortex, fMRI studies have determined that touch which preferentially targets CTs reliably produces activation in affective and reward-related brain regions (Björnsdotter et al., 2009; Gordon et al., 2013; McGlone et al., 2012; Morrison, 2016b; Olausson et al., 2002). Their response characteristics, coupled with projections to affective brain regions, has led to the so called 'affective touch hypothesis' that the CT system has a direct, evolutionary conserved role in signalling socially relevant and rewarding touch (Morrison et al., 2010; Olausson et al., 2010). Indirect support for this theory comes from observational studies which confirm that parents spontaneously caress their infant at CT optimal velocity (Bytomski et al., 2020; Croy et al., 2016b; Van Puyvelde et al., 2019a).

Several implicit behavioural studies in adults have shown that touch which optimally activates CTs carries a more positive affective value than touch delivered outside the CT-optimal velocity range (Pawling et al., 2017a). Furthermore, this rewarding value can be acquired by previously neutral social stimuli (faces) which CT targeted touch is experienced in the presence of (Pawling et al., 2017b). Also, when viewing videos of others being touched, people's vicarious ratings show the same relationship between velocity and hedonic value as when that touch is experienced first-hand (Haggarty et al., 2021; Morrison et al., 2011; Walker et al., 2017b). Taken together, these studies provide evidence that touch which optimally activates CTs has a particular rewarding value, which adults have learned to recognise, and which can, through associative learning, be acquired by other concurrently experienced social cues. The acute stress buffering effect of CT targeted touch has been demonstrated in two studies where touch delivered at a CT optimal but not a non-CT optimal velocity buffered participant ratings and neural responses to a painful stimulus

(Krahé et al., 2016), as well as self-reported feelings of rejection in a social exclusion task (von Mohr et al., 2018).

It seems likely activation of CTs plays a direct and significant role in the stress buffering benefits of affective touch (Morrison, 2016a; Walker & McGlone, 2013; Walker et al., 2017a). A number of behavioural studies report that a brief touch, delivered at CT optimal velocity, to both adults and 9-month-old infants, produced a significant reduction in heart rate in comparison to slower and faster, non-CT optimal touch (Fairhurst et al., 2014; Pawling et al., 2017a, 2017b). While, in a clinical setting, brief tactile interventions in premature infants produced a rapid and sustained decrease in heart-rate and an increase in blood oxygenation levels (Manzotti et al., 2019). In healthy young infants, a brief period of parental stroking touch, spontaneously delivered at CT-optimal velocity, produced a lasting increase in respiratory sinus arrhythmia (RSA), a component of Heart-Rate-Variability and biomarker of self-regulation capacity (Van Puyvelde et al., 2015; Van Puyvelde et al., 2019a, 2019b). In contrast, lack of parental support is known to lead to blunted RSA development (Field et al., 1995). These physiological findings provide further support for the theory that CTs are one mechanism by which early nurturing contact supports secure attachment and the development of an infant's physiological and emotional regulation (Björnsdotter et al., 2010; Craig, 2002; Fotopoulou et al., 2022; McGlone et al., 2017: Walker et al., 2022).

Anatomically, there are several plausible neural pathways via which CT activation could exert both acute and long-term stress buffering effects. In common with other C-type afferent fibres, CTs project to the brain via the spinothalamic tract from where projections to the hypothalamus and the amygdala provide potential pathways through which their input can modulate HPA axis function (Alden et al., 1994; Bernard et al., 1993; Bester et al., 1997; Wercberger & Basbaum, 2019). For example, low intensity stimulation of cutaneous somatosensory nerves, through stroking touch, warmth and light pressure, has been reported to induce the release of endogenous peptides, such as oxytocin (Nummenmaa et al., 2016; Okabe et al., 2015; Stock & Uvnäs-Moberg, 1988; Uvnäs-Moberg et al., 2015). Oxytocin can acutely buffer stress responses through direct and indirect inhibition of the HPA axis via hypothalamic projections to regulatory brain regions including the amygdala and hippocampus (Uvnäs-Moberg et al., 2015; Walker et al., 2017a). As well as acute modulation, oxytocin also has sustained effects on stress reactivity, for example via up regulation of inhibitory alpha-2-adreno receptors on noradrenergic neurons of the locus coeruleus projecting to neurons in the paraventricular nucleus of the hypothalamus which produce and release corticotropin-releasing hormone. The net effect of which is enhanced inhibition of the HPA axis (Díaz-Cabiale et al., 2000; Petersson et al., 1998, 2005), thus offering a potential neuroendocrine mechanism by which affective touch can buffer against the deleterious effects of exposure to chronic stress (Uvnäs-Moberg et al., 2015; Walkeret al., 2017a).

Cortically, the posterior insula cortex is a key target of CT input (Gauriau & Bernard, 2004; Olausson et al., 2002; Polgár et al., 2010). While being one of the earliest cortical structures to differentiate (Afif et al., 2007; Alcauter et al., 2015; Huang et al., 2006; Kalani et al., 2009; Wai et al., 2008), the insula cortex undergoes an extended developmental trajectory, peaking in volume at around 18 years of age (Shaw et al., 2008). FMRI studies have also demonstrated the involvement of affective regions such as orbitofrontal cortex, medial prefrontal cortex, and the amygdala in processing affective touch (Bennett et al., 2014; Gordon et al., 2013; Kaiser et al., 2016; McDonald et al., 1999; McGlone et al., 2012). Thus, affective touch activates brain regions whose structure and function are known to be significantly impacted by an infant's early social environment and exposure to stress. Indeed, the posterior insula is known to mediate the stress buffering effects of safety signals via inhibition of the basolateral amygdala (Christianson et al., 2008, 2011). If CTs function to signal the reward associated with physical contact to conspecifics, aiding maintenance of homeostatic balance, their activation could, via this pathway, blunt the impact of repeated stressors (Morrison, 2016a). Given its centrality to early life social interactions, it is possible that affective touch is the original rewarding safety signal which later comes to be associated with secure attachment.

Importantly, when examining the role and application of CT touch, the role of social norms and cultural differences must be acknowledged (Dibiase & Gunnoe, 2004; Jewitt et al., 2020). In their 2020 paper, Sorokowska and colleagues examined individual predictors of differences in affective touch behaviours, including age, sex, and distance preference, alongside cultural predictors such as temperature, collectivism, conservatism, and religion across 45 countries. Although differences in touch diversity and prevalence were reported, they found that touch was most prevalent between partners and children, irrespective of culture or location (Sorokowska et al., 2021). This suggests that affective touch in close relationships may have the potential to cut across cultural, economic, and global boundaries.

Corresponding, individual differences in sensitivity to the rewarding value of CT targeted, affective touch have been reported (Croy et al., 2016a; Croy et al., 2021; Crucianelli et al., 2016; Devine et al., 2020; Krahé et al., 2018; Sailer & Ackerley, 2017). For example, a group of care-experienced young adults reported more negative experiences of childhood touch and made more blunted ratings of CT targeted touch than age matched peers who grew up in a traditional family setting (Devine et al., 2020). Individuals with anxiety have reported touch aversion and tactile anhedonia (Strauss et al., 2019). Thus, the effects of touch may not be equal for everyone, which provides support for the hypothesis that the benefits of touch are related to early life experiences and attachment style (Jakubiak & Feeney, 2017).

Attachment and touch

Surprisingly, only limited work has been conducted looking at the regulatory role of touch on the development of attachment security in humans (Duhn, 2010; Jakubiak & Feeney, 2016); however, human studies have suggested that increased physical contact between a caregiver and infant does promote secure attachment (Norholt, 2020). Ainsworth and colleagues reported differences in frequency and quality of touch during the strange situation manipulation, with secure children being the recipients of more frequent touch from their caregiver, while insecure children received less touch or less comforting touch (Ainsworth et al., 1978).

Recent cross-sectional studies have reported a significant positive relationship between self-reported experiences of touch during childhood and adolescence and both, adult attachment style, and adult experiences of affective touch (Beltrán et al., 2020; Trotter et al., 2018). Those with an anxious orientation perceive touch positively (Carmichael et al., 2021) and while they desire more touch from romantic partners (Brennan et al., 1998), this seems to be unrelated to daily touch provision (Carmichael et al., 2021). In fact, little difference has been found in touch behaviours between those with secure and anxious attachments (Chopik et al., 2014). For those with avoidant or disorganised orientations, it has been suggested that touch may be more aversive and they engage in less touch behaviours (Debrot et al., 2021; Jakubiak et al., 2021; Tucker & Anders, 1998). Correspondingly, participants classified as having an anxious attachment orientation showed reduced discrimination of the hedonic value of CT-targeted vs. non-CT targeted, faster velocity touch; whereas, avoidant attachment did not benefit from the buffering effects of affective touch on neural and subjective responses to a painful stimulus (Krahé et al., 2016).

Touch may attenuate stress reactivity in securely attached individuals while, for those individuals who desire autonomy, it may have the opposite effect (Krahé et al., 2018). Individuals higher in attachment avoidance demonstrate activation of emotion processing brain regions when experiencing a caress like touch (Spitoni et al., 2020), suggesting that when touch is not desired, for any reason, it may be interpreted as intrusive or unpleasant (Jakubiak & Feeney, 2017). Relatedly, context seems particularly salient for those with higher levels of avoidant attachment when exploring the benefits of touch (Carmichael et al., 2021). Taken together, these studies suggest that a person’s social history affects their later life sensitivity to the specific rewarding value touch and of CT targeted, affective touch.

Future directions

Given the over-whelming evidence that adverse early life experience is associated with attachment insecurity, stress dysregulation, and a multitude of mental and physical health risk factors, it is not surprising that interventions have been developed to try and undo the damage done (Berlin et al., 2018; Kirlic et al., 2020). Emphasis has been placed on improving attachment security in infants and young people while they are still developmentally malleable (Valadez et al., 2020). This can be approached directly or indirectly. Indirect interventions address psychosocial risk factors thought to impair the bonding process (e.g., maternal depression, social support) (Stein et al., 2018). Direct approaches focus on the caregivers' sensitivity and responsiveness to their infant's signals of distress or discomfort (Marvin et al., 2002). Typically, interventions are very targeted to the most 'at risk' groups; they can be expensive, time and labour consuming, meaning real-world social care agencies attempting to meet the needs of all at-risk infants often do not have the available resources to implement them (Cassidy et al., 2013).

Although evaluation of the long-term benefits of these interventions are currently ongoing, the early results seem positive for high-risk infants (Gregory et al., 2020; Kirlic et al., 2020). For example, the attachment and biobehavioural catch-up (ABC) program (Dozier et al., 2006) teaches parents how to interact and respond sensitively to their infant. This in-home program runs over a period of 10 weeks, with structured topics, and feedback provided by an ABC trained parent-coach on parenting behaviour. The program was initially developed for foster parents but has since been extended to other high-risk groups (Dozier et al., 2018). Increases in attachment security and improvements in cortisol regulation following completion of the program and longer term follow up have been reported (Grube & Liming, 2018).

To our knowledge, no attachment intervention has yet achieved widespread implementation. As is the case with many behaviour change interventions, there are significant variations within the design and outcomes assessed, making it difficult to identify a unifying 'active' principle facilitating the process of change allowing for wider application (Michie et al., 2011). Yet the potential public health benefits of improved attachment security on a wider scale are obvious. By including those who experience low or moderate level adversity during early life, such as lack of parental warmth or non-nurturing care, may lead to increased resilience and stress management, as well as reductions in poor health outcomes (Herzberg & Gunnar, 2020; Puig et al., 2013; Vowels et al., 2022; Young et al., 2021). Attachment interventions studies recognise the importance of touch and programmes such as the ABC biobehavioural catch up features touch and nurturing behaviour as part of the curriculum (Dozier et al., 2018); however, in this and other intervention programmes it is not clear how, or if, touch is systematically recorded or coded (Botero et al., 2020).

As outlined by Botero et al. (2020) the omission of touch in intervention research and practice needs to be addressed. Health Psychologists know better than anyone else that prevention is better than a cure; however, many attachment interventions are *reactive*, but if it can be established that affective touch is this missing 'active ingredient' that underlies attachment security, this 'bottom up' approach could be applied to the development of *preventative* behavioural interventions on a wider scale. This means more work is needed on touch frequency and quality within existing interventions, but more importantly, touch needs to be examined within the dyad, across different contexts for reciprocity and function to help delineate these associations (Kirsch et al., 2018; Mantis & Stack, 2018).

Health Psychologists and health care practitioners can already begin to utilise what we know about attachment and touch when considering health behaviours and practices. Establishing connections between attachment, stress, and touch may offer benefits to adults, particularly in situations which may be distressing, such as illness (Krahé et al., 2016; von Mohr et al., 2018). If we can understand variation in stress responsivity between individuals, we can perhaps improve health care uptake and outcomes (Kidd et al., 2014; Maunder & Hunter, 2016). For example, in health care settings where attachment strategies are likely to be activated, the presence or absence of affective touch could increase or minimise distress (Krahé et al., 2016).

Conclusions

Inevitably, no review is ever able to fully address all relevant material, especially for a cross disciplinary topic. There are many parts of this story that deserve further and detailed consideration that are beyond the scope of this review. Both limitations and current areas of debate in affective touch research have been discussed elsewhere (Cruciani et al., 2021; Schirmer & McGlone, 2022). Nor have we looked at if giving touch results in similar benefits to receiving touch (Triscoli et al., 2017). Similar debates can be found in the attachment literature on attachment stability and change, attachment across cultures, and if attachment is universal (Thompson et al., 2022). Instead, we set out to introduce a relatively unexplored field in health psychology, affective touch, that may enable us to understand *how* close relationships may influence the development and function of stress systems that contribute to health outcomes. In addition, we encourage researchers to incorporate touch into existing interventions and in health care settings to add to this rapidly growing research field.

In summary, the data reviewed here proposed that there is a specific system of nerves in the skin well adapted to signal the rewarding and protective value of affiliative tactile interactions and promotion of secure attachment bonds. Furthermore, via their modulation of central nervous system, endocrine and autonomic system functions, early experience of affective touch may well contribute significantly to both acute and long-term stress buffering effects. Indeed, sensitivity to these stress buffering effects seems likely to be predicted by an individual's early nurturing experiences and attachment style. Such mechanistic insights or 'bottom up' approaches offer neurobiological and psychological targets for the development, assessment and implementation of evidence based social and tactile interventions to support resilient functioning in the health psychology domain.

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