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THE SHARED NEURAL SUBSTRATES OF PHYSICAL AND SOCIAL PAIN

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In her 1937 self-portrait *Memory*, artist Frida Kahlo depicted the anguish roused by her husband's infidelity with her sister as a metal spike being driven through a gaping hole in her chest. Similarly, when reaching out for words to describe experiences of social loss or rejection, we often clothe our distress in the language of physical pain. A harsh criticism from an admired colleague stings, rejection of romantic overtures hurts, the death of a loved one leaves us heartsick, and the withdrawal of a partner's love cuts to the core, causing scars. Unlike some other evocative English expressions that do not stand up well to translation, reliance on physical pain metaphors to describe social pain is universal, spanning languages as diverse as German and Inuktitut (MacDonald & Leary, 2005). The universality of this finding raises the question of whether this linguistic tendency reveals something fundamental about the way humans experience threats to social connection. In other words, what is the reason why we gravitate towards physical pain metaphors when describing social distress, or why images like the one evoked by Frida Kahlo resonate so powerfully with audiences around the world, regardless of their language or cultural background?

In recent years, an accumulating body of empirical evidence has supported the theory that there is overlap in the neurobiological systems that process physical and social pain (Eisenberger & Lieberman, 2004; Eisenberger, Lieberman, & Williams, 2003; Eisenberger, 2012, 2015; MacDonald & Leary, 2005; Panksepp, 1998). That is, social pain – the emotional response to any negative social event that threatens or damages our sense of connection to other people – shares some neural and neurochemical substrates with physical pain. In this chapter we explain the potential adaptive value of a social injury detection system built on top of a physical pain system, review social neuroscience evidence for the physical-social pain overlap, and explore several implications of such an overlap. We also address some recent criticisms of the physical-social pain overlap theory.

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The Evolution and Adaptive Value of Social Pain

Our social bonds are a precious resource. At birth, humans are utterly dependent on their caregivers for life-sustaining care and nourishment (Bowlby, 1969). In our evolutionary past, group living bolstered our ancestors' chances of reproductive success and survival throughout the lifespan by providing help with challenges such as hunting, foraging, predator defense, and child-rearing, as well as by increasing access to mates (Baumeister & Leary, 1995). Social support was also indispensable for the survival of individuals severely debilitated by illness or injury (Hublin, 2009). As solitary humans were not well equipped to take on the demands of their environment by themselves, it follows that evolution would favor the emergence of biological mechanisms that signaled potential or impending threats to social connection and furnished the motivation to avoid social disconnection and to repair and maintain social ties.

Social-physical pain overlap theory (Eisenberger & Lieberman, 2004; MacDonald & Leary, 2005; Panksepp, 1998) postulates that one such mechanism is the social pain system, which emerged by co-opting the evolutionarily ancient substrates involved in the processing of physical pain. Physical pain helps to minimize tissue damage and maintain safety in the face of physical threat by capturing attention and focusing it on the noxious stimulus, motivating behavior to escape the source of injury, encouraging recuperation, and promoting learning and avoidance of similar danger in the future (Eccleston & Crombez, 1999). In a deeply social species, for whom preservation of social ties is just as critical as preservation of the physical body, a system with these properties would be highly adaptive for responding to threats to social connection and encouraging proximity to critical caregivers and other conspecifics.

Although many questions about the precise nature, extent, and boundaries of the social-physical pain overlap remain, researchers are beginning to gain a better understanding of the physiological mechanisms involved in processing social pain. In the next several sections, we review the shared neurochemical and neural substrates of physical and social pain.

Pharmacological Evidence for the Social-Physical Pain Overlap

Opiates ... most blessed power in those moments of pain and languor,
when the whole head is sore, and the whole heart sick.

Walter Scott (Scott, 1887)

The idea that opiate drugs such as morphine, known for millennia for their highly potent pain-relieving properties, may also alleviate psychological aches and fill the gaps left by broken or missing relationships is a long-standing cultural trope, spanning from Homer's *Odyssey* (Brownstein, 1993) to modern TV shows like *House*. Along similar lines, laypeople and scholars alike have drawn parallels

between love and addiction, employing metaphors like “interpersonal heroin” to describe the pulls of romantic bonds (Peele & Brodsky, 1974; Panksepp, 1998). Interestingly, a systematic program of research beginning in the 1970s has suggested that the endogenous opioid system (the site of action for drugs like morphine and heroin) indeed plays a crucial part in regulating social attachment, perhaps explaining, in part, why social connection feels so good and why loss of that connection feels so painful.

The endogenous opioid system comprises a family of opioid peptides (e.g., endorphins) and corresponding receptors, broadly distributed throughout the central and peripheral nervous systems, where these naturally occurring peptides (as well as the opioid drugs that mimic their effects) bind (Le Merrer, Becker, Belfort, & Kieffer, 2009). This system plays an essential role in dampening physical pain (Fields, 2007) and reinforcing the hedonic value of rewards such as palatable food, sex, and mood-elevating drugs (Le Merrer et al., 2009). Given the dual roles of endogenous opioids in mediating reward and pain, this system may be ideally situated to regulate social attachment by giving rise both to the pleasures of social closeness and the pain of social isolation (MacLean, 1990; Panksepp, 1998). Specifically, the Brain Opioid Theory of Social Attachment (Machin & Dunbar, 2011; Panksepp, 1998) postulates that social contact triggers the release of endogenous opioids, which reinforces the social bond by giving rise to feelings of reward, and that the loss of social contact results in a drop in endogenous opioid levels, which underlies feelings of social pain and motivates pursuit of social proximity in order to alleviate this aversive state.

Consistent with this theory, animal research has found that morphine, which exerts its pain-relieving effects primarily by activating a subtype of opioid receptors called μ -opioid receptors (Matthes et al., 1996), also reduces social isolation distress (assessed with a specific type of call named a distress vocalization) in a variety of animal species (e.g., Herman & Panksepp, 1978; Panksepp, Vilberg, & Bean, 1978; see Machin & Dunbar, 2011, for a review). Contrastingly, opioid receptor antagonists, which block endogenous opioid receptors, reduce the quieting typically seen when animals are reunited with their mother or littermates (e.g., Herman & Panksepp, 1978; Martel, Nevison, Simpson, & Keverne, 1995; see Machin & Dunbar, 2011, for a review). These findings are consistent with the hypothesis that isolation distress reflects a state of endogenous opioid withdrawal, and that social contact assuages this distress by increasing opioid levels.

Given the pivotal role the endogenous opioid system plays in social bonding, it is not surprising that elimination of the μ -opioid receptor through genetic engineering leads to severe deficits in attachment, including lack of distress vocalizing (without affecting vocal responses to other stimuli such as cold temperatures; Moles et al., 2004). In addition to identifying a potential shared neurochemical pathway underlying both physical and social pain, work on the endogenous opioid system also illustrates the broader idea that the capacity for social pain is an integral part of attachment. That is, the pleasures of closeness and

the pain of social loss are closely linked, and both are necessary for maintenance of social bonds (Resendez & Aragona, 2013).

Neural Evidence for the Social-Physical Pain Overlap

Neural Substrates of Physical Pain

At first blush, the idea that social and physical pain experiences are processed similarly at the neural level may appear surprising since we register these two types of threats through different sensory modalities (harsh words, unlike harsh blows, do not act on pain receptors in the skin). It is important to note, therefore, that physical pain is a multifaceted experience comprising two related, yet dissociable, components: The sensory-discriminative and the affective-motivational (Ploner, Freund, & Schnitzler, 1999; Rainville, Duncan, Price, Carrier, & Bushnell, 1997; Treede, Kenshalo, Gracely, & Jones, 1999). The sensory-discriminative aspect of pain processing provides information about the location, quality (e.g., pinprick versus burn), and intensity of a pain stimulus. However, the mere identification of a pain stimulus, regardless of its perceived intensity, does not necessarily mean that the stimulus will *feel* bothersome. The affective-motivational component of pain, by contrast, involves the aversive feelings of distress that accompany noxious stimulation, as well as the motivational drive to escape the source of pain. The dissociation between these two pain processing components is dramatically evident in the case of individuals with pain asymbolia, who do not experience any suffering in response to pain stimuli (i.e., they lack the affective component of pain), even though their sensory-discriminative abilities remain fully intact (Berthier, Starkstein, & Leiguarda, 1988). Notably, these patients frequently suffer serious physical injuries because they fail to avoid or adequately respond to physical threat and damage; evidently, stripped of its affective component, pain experience loses its motivational force.

The sensory-discriminative and affective-motivational components of pain processing have different neural substrates. The former component is processed by the primary and secondary somatosensory cortices (SI and SII) and the posterior insula (PI; Schnitzler & Ploner, 2000). Individuals with damage in these areas may have difficulty identifying and localizing a noxious stimulus, although they still experience the pain as aversive and show appropriate avoidance behavior (Ploner et al., 1999). Conversely, pain affect is processed primarily in the dorsal anterior cingulate cortex (dACC) and the anterior insula (AI). Individuals with lesions to the dACC or the AI still report being able to perceive pain, but are less bothered and distracted by it (Berthier et al., 1988).

As experiences of social pain do not involve direct somatosensory input, and because the affective component of pain is particularly relevant for driving the motivation to respond to threat, it seems likely that social pain processing would primarily rely on brain regions involved in pain affect. As we will show in our

review, this indeed appears to be the case, although a handful of social pain studies have observed neural activation in sensory-discriminative regions as well.

Another brain region responsive to physical pain is the periaqueductal grey (PAG; Linnman, Moulton, Barmettler, Becerra, & Borsook, 2012), which receives both bottom up pain input from pain receptors in tissue (Craig & Dostrovsky, 1999) and top down input from the ACC (An, Bandler, Ongür, & Price, 1998). This region is part of a neural circuit that can either increase or decrease the pain signal depending on the motivational context (e.g., the presence of reward or an even larger threat) that prevails during physical injury (Fields, 2007). For example, the PAG may inhibit pain during an on-going confrontation with a threat in order to allow the animal to engage in emergency fight-or-flight behavior. As we will see, this region is implicated in social pain processing as well.

Neuropsychological Evidence

ACC

Evidence from comparative neuroanatomical, lesion, and stimulation studies performed in animals suggests that some of the physical pain processing regions, like the ACC and PAG, play an important role in regulating social motivation and attachment-related processes, including separation distress. As MacLean (1990) notes, the emergence of the thalamocingulate division of the limbic system, which comprises the cingulate cortex and its innervating thalamic nuclei, accompanied the evolutionary transition from reptiles, who do not display any mother-offspring attachment, to mammals, whose survival is predicated on this attachment bond. One key attachment behavior in mammals is distress vocalizing, which is crucial for maintaining mother-offspring contact and, as was previously discussed, is inferred to be a manifestation of separation distress. Paralleling the involvement of the ACC in physical pain, electrical stimulation of the ACC results in the production of distress calls (Smith, 1945), whereas lesions to the ACC (dorsal and/or ventral to the genu) reduce distress vocalizations (Hadland, Rushworth, Gaffan, & Passingham, 2003; MacLean & Newman, 1988).

Furthermore, animals with cingulate lesions exhibit impairments in maternal care (Slotnick, 1967; Stamm, 1955) and decreases in affiliative behavior towards conspecifics (e.g., Hadland et al., 2003; Rudebeck et al., 2007; Ward, 1948). Notably, the apparent reduction in need for social closeness that these animals show does not appear to be accompanied by loss of interest for novel or rewarding stimuli in general (Hadland et al., 2003; Rudebeck et al., 2007). These findings are consistent with the idea that brain regions involved in processing social pain should also contribute to social motivation, dovetailing with our earlier discussion of the endogenous opioid system.

Unfortunately, no studies have investigated the effects of cingulate lesions on social pain experience in humans. Interestingly, however, some case studies do

implicate the ACC in social motivation. For example, Tow and Whitty (1953) reported that patients who had undergone a cingulotomy (a surgical treatment for intractable pain and psychiatric disorders that involves lesioning the dACC) subsequently exhibited social disinhibition and reductions in self-consciousness and concern about the opinions of others, all of which could be indicative of lowered sensitivity to social pain.

PAG

Similarly to the ACC, the PAG also exerts control over separation distress and other attachment behaviors in animals. PAG lesions reduce distress vocalizations (Newman & MacLean, 1982; Wiedenmayer, Goodwin, & Barr, 2000), whereas electrical stimulation of the PAG increases such vocalizations (e.g., Jürgens & Ploog, 1970; Newman & MacLean, 1982; Panksepp, Normansell, Herman, Bishop, & Crepeau, 1988). Furthermore, one study using microelectrode recording within the PAG found a cluster of units in the PAG to be associated with distress vocalizations (Larson, 1991). Additionally, PAG lesions lead to impairments in maternal behavior (Lonstein & Stern, 1997), suggesting that this region has broader relevance for social bonding.

Neuroimaging Evidence

Neural correlates of social pain

The most direct evidence for the neural overlap between physical and social pain comes from functional magnetic resonance imaging (fMRI) studies. In the first experiment of this kind to look at social exclusion, Eisenberger, Lieberman, and Williams (2003) scanned participants while they were engaged in a computerized ball-tossing game called Cyberball. Although participants believed that they were playing the game with real people via the Internet, the other players were actually controlled by a computer script programmed to exclude the participant from the game partway through the experiment. The scan revealed increased activation in the dACC and AI when participants suddenly stopped receiving all ball tosses from their fellow players. Furthermore, the extent of dACC activation was positively correlated with participants' self-reported feelings of social exclusion, such that those who felt most rejected also exhibited the highest levels of dACC reactivity. These findings suggested that brain regions often involved in processing physical pain are recruited during the experience of ostracism as well.

Subsequent studies using Cyberball replicated these findings, showing that social exclusion is accompanied by increased activation in the dACC and/or AI (e.g., Kawamoto et al., 2012; Masten, Telzer, & Eisenberger, 2011; Masten, Telzer, Fuligni, Lieberman, & Eisenberger, 2012; see Eisenberger, 2015, for a review). Furthermore, dACC (DeWall et al., 2012; Eisenberger, Gable, & Lieberman, 2007;

Onoda et al., 2009) and AI (DeWall et al., 2012; Masten et al., 2009) activity has again been found to positively correlate with self-reported feelings of social exclusion, as well as observer-rated social distress (Masten et al., 2011).

Experiments employing other social pain induction paradigms have obtained similar findings. Kross, Berman, Mischel, Smith and Wager (2011) recruited participants who had recently undergone an unwanted breakup and carried out a direct comparison of neural activation exhibited during a social pain condition, in which participants viewed a photograph of their ex-partner, and a physical pain condition, in which a painful heat stimulus was applied to their arm. Consistent with earlier findings, the researchers observed overlapping activation in the dACC and AI in response to both types of pain. Interestingly, there was also overlapping activation in the SII and PI, suggesting that certain social pain experiences may involve a somatosensory component as well (an intriguing finding given that somatic symptoms are sometimes reported after social pain experiences; Leary & Springer, 2001).

In another study of romantic rejection (Cooper, Dunne, Furey, & O'Doherty, 2014), participants attended a speed-dating event where they got to meet potential romantic partners in a series of mini "dates." In a subsequent scanning session, participants found out the outcome of each date (i.e., whether each speed-dater had expressed interest in seeing them again). Analyses revealed increased dACC activation in rejection trials (i.e., trials in which participants' interest in a partner was unrequited), compared to trials where neither partner had expressed romantic interest.

Neuroimaging methods have also been used to examine the neural substrates of grief during bereavement, another particularly potent type of social pain. Viewing pictures of a deceased relative activates the dACC and insula (Gündel, O'Connor, Littrell, Fort, & Lane, 2003; O'Connor et al., 2008), as well as the PAG (O'Connor et al., 2008). Kersting and colleagues (2009) obtained similar findings in a group of women grieving after an induced termination of pregnancy due to fetal abnormality. Specifically, the authors observed increased dACC and PAG activation in response to images of happy baby faces in bereaved women, relative to control women who had successfully delivered their child.

These pain-related brain regions have also been shown to be sensitive to negative social evaluation. Specifically, decreases in state self-esteem that accompany negative social evaluation – for example, being told that you are boring – correspond to increased dACC and AI activity (Eisenberger, Inagaki, Muscatell, Byrne Haltom, & Leary, 2011). Furthermore, Wager and colleagues (2009) have used a common and highly effective social stress paradigm (Trier Social Stress Test) to show that social evaluative threat (i.e., a context where the self can be judged negatively by others) leads to activation in the dACC and the PAG.

Finally, even symbolic reminders of social disconnection may be enough to induce pain-related neural activation. Specifically, viewing artwork depicting themes of rejection and loneliness induces dACC and AI activation, relative to images depicting acceptance (Kross, Egner, Ochsner, Hirsch, & Downey, 2007).

Individual Differences

To the extent that certain individual differences are known to modulate social pain sensitivity, we would expect to see the influence of these factors reflected in varying levels of neural activation in pain-related brain regions during social exclusion. Indeed, evidence from a number of studies has supported this prediction. Our history of interactions with other people – and ensuing expectations about the quality of social support available to us – greatly shapes our ability to handle social threat and rejection (Mikulincer & Shaver, 2007). Accordingly, individuals who spent more time with friends in adolescence show less exclusion-related activity in the dACC and AI (Masten et al., 2012), and those who report higher levels of daily support exhibit reduced activity in the dACC and the PAG in response to social exclusion (Eisenberger et al., 2007).

Contrastingly, adolescents with a history of chronic peer rejection during childhood show higher levels of dACC activation during exclusion (Will, van Lier, Crone, & Güroğlu, 2015). Furthermore, anxious attachment – which is characterized by chronic and excessive preoccupations about the availability of social support, stemming from a history of volatile and inconsistent interactions with intimate others (Mikulincer & Shaver, 2007) – is related to higher dACC and AI activation in response to social exclusion (DeWall et al., 2012). Similarly, low self-esteem, which reflects the extent to which we believe we are socially acceptable (Leary & Baumeister, 2000), also predicts higher levels of dACC reactivity in response to social threat (Onoda et al., 2010). Altogether, these findings suggest that brain regions involved in social pain processing are sensitive to the perceived availability of social resources.

Furthermore, trait rejection sensitivity positively correlates with dACC reactivity to disapproving facial expressions (Burklund, Eisenberger, & Lieberman, 2007) and to social exclusion during Cyberball (Masten et al., 2009). Additionally, narcissists, who have low implicit self-esteem (Jordan, Spencer, Zanna, Hoshino-Browne, & Correll, 2003) and are particularly reliant on others for maintenance of their positive self-views (Morf & Rhodewalt, 2001), exhibit higher levels of dACC and AI activation during Cyberball exclusion (Cascio, Konrath, & Falk, 2015).

Controversies

As this review has shown, a considerable number of studies, employing different methodologies and examining various types of social pain experience (e.g., bereavement, social evaluative threat, romantic rejection) have observed activation in physical pain-related brain regions. Furthermore, the most comprehensive meta-analysis of social pain studies to date has confirmed that the dACC is active during social exclusion, and that the extent of this activation corresponds to self-reported feelings of social distress (Rotge et al., 2015). However, the interpretation that these findings reflect a neural overlap between

social and physical pain has been challenged in recent years. These challenges have primarily revolved around competing interpretations of what the neural activation in these brain regions – and particularly the dACC – actually means. That is, does it reflect pain experience, or something else entirely? In the following section, we briefly highlight some of the discussions in the field (for a more comprehensive review, see Eisenberger, 2015).

The initial criticism of the original Eisenberger, Lieberman, and Williams (2003) study forwarded the idea that dACC activation during Cyberball exclusion reflects expectancy violation, rather than pain. This was consistent with the then-dominant cognitive account of the dACC as a discrepancy-monitoring and conflict-processing region, involved primarily during tasks like the Stroop test (Bush, Luu, & Posner, 2000). Consequently, Somerville, Heatherton, and Kelley (2006) proposed that Cyberball exclusion violated participants' expectations of inclusion, which induced dACC activation.

However, this hypothesis does not account for the finding that dACC activity correlates with self-reported feelings of social exclusion, or the fact that dACC activation is seen across a number of other social pain studies where expectancy violation is not a plausible mechanism. For example, individuals high on trait rejection sensitivity, who by definition chronically expect social rejection (Downey & Feldman, 1996), exhibit higher dACC reactivity to social threat (Burklund et al., 2007; Masten et al., 2009). Furthermore, a variation of Cyberball that controlled for expectancy violation by including an overinclusion condition, in which participants received the ball a disproportionately large per cent of the time, still showed greater dACC activation in the exclusion condition relative to the overinclusion condition (Kawamoto et al., 2012).

Finally, it should be noted that the cognitive and affective accounts of dACC activity during exclusion are not incompatible. Rather, Eisenberger and Lieberman (2004) have proposed that the dACC may function as a sort of neural alarm that detects discrepancies between desired outcomes (e.g., social inclusion) and the reality (cognitive function), and then gives rise to aversive affect as a way of “sounding the alarm” (affective function). Consequently, the cognitive and affective roles of the dACC may be complementary in responding to social threat (Spunt, Lieberman, Cohen, & Eisenberger, 2012).

Another criticism of the physical-social pain overlap theory has proposed that activation in the pain matrix (dACC, AI, PI, SI, and SII) reflects salience processing rather than pain (Iannetti, Salomons, Moayedi, Mouraux, & Davis, 2013) and thus, the fact that social pain activates these regions is not indicative of pain, but rather of salience. Salience refers to the quality of a stimulus that makes it stand out against its environment (e.g., a loud noise in an otherwise quiet room). To the extent that painful stimuli are highly salient, this explanation seems plausible.

However, several studies contradict this interpretation. In accordance with the salience hypothesis, we would expect to see the highest levels of neural activation in the “salience network” when two salient stimuli are combined. However,

when participants viewed pictures of their loved ones (highly salient positive stimulus) while receiving physical pain (highly salient negative stimulus), they actually showed reduced, rather than enhanced, activation in the dACC and AI in response to physical pain (Eisenberger, Master, et al., 2011; Younger, Aron, Parke, Chatterjee, & Mackey, 2010). Similarly, Choi, Padmala, Spechler, and Pessoa (2014) examined simultaneous activation in the brain regions implicated in salience processing in response to physical pain and reward (another highly salient stimulus). Here too, the authors found competitive interference between pain and reward stimuli, such that the effect of reward was reduced during threat, and vice versa. Altogether, these findings suggest that salience processing does not provide a better account of the data obtained in social pain studies.

Summary

Taken together with the pharmacological and neuropsychological evidence reviewed earlier, neuroimaging studies of social pain provide a compelling case for a neurobiological overlap between social and physical pain. In the next section, we discuss two corollaries that stem from the theory that physical and social pain share overlapping neurochemical and neural substrates. First, we explore whether factors that render some individuals particularly sensitive to physical and social pain are related. Second, we examine whether manipulations that increase or decrease one type of pain experience have a parallel effect on the other type of pain experience.

Consequences of a Physical-Social Pain Overlap

Shared Sensitivity to Physical and Social Pain

If physical and social pain experiences are underpinned by similar neurobiological substrates, we may expect individuals who exhibit enhanced sensitivity to one type of pain to exhibit enhanced sensitivity to the other type of pain as well. Indeed, a number of personality traits, such as anxious attachment and neuroticism, relate both to increased interpersonal sensitivity and the propensity to experience more physical pain (for reviews, see Eisenberger, 2012; MacDonald & Leary, 2005). Furthermore, chronic pain patients report more fear and avoidance of social situations (Asmundson, Norton, & Jacobson, 1996), suggestive of increased sensitivity to social pain. Similarly, an experiment directly testing this relationship in healthy controls found that greater baseline sensitivity to a thermal pain stimulus correlates with heightened self-reported feelings of rejection during Cyberball exclusion (Eisenberger, Jarcho, Lieberman, & Naliboff, 2006).

Additionally, variation in the μ -opioid receptor gene (OPRM1) moderates physical and social pain sensitivity in a parallel manner. Specifically, the G allele of this gene, which has been linked with increased physical pain sensitivity (Sia et al.,

2008), is also associated with increased rejection sensitivity and increased dACC and AI reactivity to Cyberball exclusion (Way, Taylor, & Eisenberger, 2009). Additionally, this same G allele increases the risk of developing depression following a rejection event (but not a negative, rejection-unrelated event; Slavich, Tarter, Brennan, & Hammen, 2014), further supporting the idea that this polymorphism underlies interpersonal sensitivity and proffering a potential physiological explanation for the link between depression and chronic pain (Fishbain, Cutler, Rosomoff, & Rosomoff, 1997).

Mutually Influential Effects of Physical and Social Pain

Another prediction derived from the physical-social pain overlap theory is that any factor that increases or decreases physical pain should have a corresponding effect on social pain, and vice versa.

For example, analgesics that alleviate physical pain may be expected to decrease social pain as well. Indeed, as we reviewed earlier in the chapter, opioid drugs like morphine, which are a mainstay in physical pain management, are also effective in reducing separation distress in a variety of non-human animal species. Although no published studies have yet directly examined the effects of exogenous opioids on social pain in humans, a double-blind, placebo-controlled experiment showed that participants taking acetaminophen, a common over-the-counter analgesic, daily for two weeks reported lower levels of hurt feelings in their daily lives and exhibited less dACC and AI activation during Cyberball (DeWall et al., 2010). This suggests that factors that reduce physical pain can reduce social pain as well.

Conversely, factors that potentiate physical pain appear to increase social pain experience. One such factor is the inflammatory response mounted by the immune system to defend against pathogens and injury. Inflammation enhances physical pain, which is an adaptive response designed to encourage rest and recuperation (Maier & Watkins, 1998). Paralleling this effect, experimental administration of a bacterial agent that elicits a temporary inflammatory response was also shown to induce feelings of social disconnection (Eisenberger, Inagaki, Mashal, & Irwin, 2010). Furthermore, individuals who exhibited the greatest increases in inflammatory activity in response to the challenge also showed the most dACC and AI activation during social exclusion.

Just as analgesics diminish social pain, we would also expect factors that decrease social pain to decrease physical pain experience as well. Perhaps the greatest source of healing we have for dealing with psychological distress, including social pain, is social support (Mikulincer & Shaver, 2007). Interestingly, social support has also been shown to alleviate physical pain. For example, cancer patients who have more social support experience less pain (Zaza & Baine, 2002). Furthermore, experiments have found that social support or reminders of social connection (e.g., holding the hand of a loved or viewing their picture) decrease subjective pain and

pain-related neural activation (dACC, AI) during pain induction (Eisenberger, Master, et al., 2011; Master et al., 2009; Younger et al., 2010).

Finally, social and physical pain responses to social threat also run in parallel. As we discussed earlier, certain neural circuits in the brain can either increase or decrease pain responses to noxious stimuli in order to enable adaptive coping with the situation (Fields, 2007). Consequently, social threats like Cyberball that increase self-reports of social pain have been shown to lead to pain hypersensitivity on a subsequent pain task (Bernstein & Claypool, 2012), with participants who feel most excluded also reporting the highest physical pain ratings (Eisenberger et al., 2006). Contrastingly, some social pain manipulations, such as having participants interact with an unfriendly confederate (Borsook & MacDonald, 2010) or giving them a bogus personality assessment forecasting that they will end up alone in life (DeWall & Baumeister, 2006), have been simultaneously linked to both emotional numbing and physical analgesia.

One factor that may determine whether individuals respond with heightened or lowered physical pain sensitivity to a social pain manipulation is severity of the manipulation (Bernstein & Claypool, 2012). It is also possible that the motivational context of a particular social pain experience may shape the ensuing pain response. For example, research has shown that explicit social rejection triggers prevention-focused behavioral responses such as social withdrawal, whereas being ignored triggers promotion-focused responses such as increased attempts at social contact (Molden, Lucas, Gardner, Dean, & Knowles, 2009). Future research could examine whether different types of social pain experience engage different biological mechanisms to support diverging goals (e.g., seeking out a new source of social connection versus avoiding further social injury), as well as whether personality factors linked to approach versus avoidance behavioral responses to social rejection exert any influence on physical pain responses to social threat (e.g., self-esteem; Stinson, Cameron, Hoplock, & Hole, 2014). However, extant research is consistent with the idea that factors that increase social pain lead to heightened physical pain sensitivity, whereas factors that decrease social pain lead to analgesia.

Conclusions

The need to belong is one of our most fundamental motivations (Baumeister & Leary, 1995). When that need is thwarted – when we lose an important social bond or feel devalued by others – we experience profound distress. In fact, as one study found, the majority of people identify the loss of an intimate relationship as the “single most negative emotional event” of their lives (Jaremka, Gabriel, & Carvallo, 2011). Social neuroscience suggests that part of the reason why these experiences are so aversive is because social pain shares some overlap in neurobiological substrates with physical pain. Importantly, this work does not advance, or seek to advance, the view that social pain and physical pain are

indistinguishable from each other. Rather, it argues that experiences of social pain tap into the affective and motivational circuitry that safeguards us from threats that can compromise survival.

This perspective equating social disconnection to physical threat has the power to shape the way we view social pain and its sufferers. For example, by refuting the old schoolyard adage “sticks and stones may break my bones, but words will never hurt me,” this work challenges the view that bullying is less serious if it does not involve physical assault (Covin, 2013). Additionally, some of the research reviewed in this chapter has been used to inform debates surrounding the morality of solitary confinement in prisons (Brooks, 2014), contributing to the decision to overhaul this practice in California.

Perhaps less obviously, work on social pain also has the potential to influence how we approach physical pain. Although pain affect is not linearly related to, and does not necessitate, input at pain receptors in peripheral tissue, sufferers of chronic pain conditions like migraines and fibromyalgia, which do not involve discernible tissue damage, often face considerable stigma and accusations of malingering (Asbring & Narvanen, 2002). Furthermore, some chronic pain patients turn to self-injurious behavior in an attempt to legitimize their suffering (Biro, 2010). Consequently, there is value in perspectives that emphasize the affective nature of physical pain.

Finally, the study of social pain yields important insights into social attachment processes more generally. As we have argued throughout the chapter, the capacity for social pain is an integral part of our ability to connect to others. In this sense, work on social pain is essential for understanding the nature of the social bonds that profoundly shape our emotional and physical well-being (House, Umberson, & Landis, 1988; Mikulincer & Shaver, 2007).

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