We are IntechOpen,
the world's leading publisher of Open Access books
Built by scientists, for scientists

4,200
Open access books available

116,000
International authors and editors

125M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Social Pain and the Brain: How Insights from Neuroimaging Advance the Study of Social Rejection and Variants of Normal

Richard S. Pond, Jr., Stephanie B. Richman,
David S. Chester and C. Nathan DeWall

Additional information is available at the end of the chapter

1. Introduction

Imagine a time when a close loved one has given you the "silent treatment". When describing how this experience made you feel, terms such as "hurt", "pained", and "broken-hearted" may have come to mind. Most everyone at one time or another has experienced the pain of social rejection, whether it was in the form of unrequited love or in the form of punishment, such as when a social click ostracizes an outcast. Over the past decade, social psychologists have conducted a great deal of experimental research to uncover the detrimental effects of social rejection. However, social psychologists are just beginning to understand the neural basis of rejection. In the current chapter, we will review the neuroscientific research on social rejection, and we will discuss the implications from neuroimaging studies that advance theory and research in the area. Specifically, we will highlight how neuroimaging has been used to uncover the neural similarities between physical and social pain.

We will begin this chapter with a brief introduction to social rejection research. Specifically, we will review research that explores the cognitive, emotional, and behavioral consequences of rejection. We will illustrate the effects of rejection within the domains of: antisocial and prosocial behavior, self-regulation, self-defeating behaviors, and intelligent thought. We will end this section with a discussion of the research that suggests an overlap between physical and social pain.

Next we will introduce the neuroscientific approach to the study of social rejection. Specifically, we will review research that has used functional magnetic resonance imaging to help uncover the similarities between social and physical pain. In this section we will focus on activation in

the dorsal anterior cingulate cortex and the anterior insula, as they are associated with the affective component of physical and social pain. We will then discuss how acetaminophen, an over-the-counter medication for treating physical pain, reduces activity in these neural regions among rejected people.

Last, we will discuss how neuroimaging has helped social psychologists identify those individuals who are most vulnerable to social rejection. We will review research on the personality characteristics that modulate the neural responses of rejection. Specifically, we will discuss how one's level of attachment anxiety, self-esteem, and emotion differentiation (i.e., aptitude for using discrete emotion categories to capture one's felt experience) either heighten or reduce activity in the neural regions associated with the distress of social rejection.

2. Why is there social pain?

The desire for social connection is among the most basic of human motivations. This desire is so strong that is has become known as a need, specifically the "need to belong" (Baumeister & Leary, 1995). All people in all cultures, to at least some degree, have an innate need to form and maintain interpersonal relationships. This need most likely developed over the course of evolutionary history, as social animals like humans have always depended on others for survival. In ancient times, groups provided a variety of advantages to their members (see Axelrod & Hamilton, 1981; Barash, 1977; Buss, 1990, 1991; Hogan et al., 1985; Moreland, 1987). Such advantages include providing mates, sharing resources, and helping to care for offspring. Tasks necessary for survival in ancient times, such as hunting large animals or keeping vigilance against predators, were best accomplished by group cooperation. Even today, people still remain dependent on other people for their survival. Most of us do not grow our own food, sew our own clothes, or build our own houses, just to name a few. Natural selection thus favors those who are motivated to be included, as such people are more likely to survive and reproduce.

In order to ensure that people continued associating with others, they required a system that motivates quick responses to signs of exclusion and punishes those who do not avoid it (MacDonald & Leary, 2005). Such a system would motivate people to identify social acceptance and seek out interpersonal relationships. Over time, humans have developed such a system. The "need to belong" creates in people a fundamental need for positive, enduring relationships with others as well as aversive reactions to a lack of social connection (Baumeister & Leary, 1995). The joy people experience after satisfying their need to belong in a group setting, as well as the consequences they face after their state of belongingness is thwarted, should work as a motivating factor to avoid social exclusion and seek out interpersonal relationships.

3. Responses to social pain

If the need to belong is not met or if it is thwarted, people suffer a host of deleterious physical and psychological consequences. Social exclusion thwarts the need to belong, because it is

directly contrary to the desired state of social acceptance. Thus, as we present below, exclusion is extremely aversive and people's bodies and minds react accordingly. Exclusion leads people to feel social pain, similar to how being injured leads people to feel physical pain. Additional consequences of social exclusion include impairments in cognitive functioning, increased aggressive behavior, self-defeating behavior, and self-regulatory deficits. Social exclusion can lead to positive behaviors as well, but only if such behaviors have a chance of promoting social acceptance. Each of these consequences to social exclusion will be presented and discussed in the sections below.

3.1. Cognitive responses

Social exclusion reduces cognitive performance. Participants who were told they would end up alone later in life (future alone condition), compared to those who were told they would have lots of friends (future belonging condition) or those who were told they would be accident-prone (misfortune control), attempted fewer problems and answered fewer questions correctly on the General Mental Abilities Test (Baumeister et al., 2002: for a description of the GMAT see Janda, 1996 and Janda et al., 1995). Participants in the future alone condition also performed worse on difficult GRE questions about a passage they had read, compared to those in the other two conditions. Finally, future alone participants were no different in their ability to correctly recall nonsense syllables but did show relatively poor performance on analytical GRE questions, compared to participants in the two control conditions (Baumeister et al., 2002). Social exclusion leads to cognitive deficits that specifically impair logic and reasoning ability, although not simple recall. These findings speak to the view that exclusion leads to a deficit in controlled processes and executive functions, potentially because of the need to devote one's self-regulatory resources to stifling emotional distress brought about by social exclusion.

3.2. Impact on self-control

As suggested above, social exclusion may impact one's use of self-regulatory resources. Indeed, social exclusion does deplete people's self-regulatory energy. For example, participants who were told they would end up alone later in life, compared to those who were told that they would have lots of friends or those who were told that they would be accident-prone, were less able to make themselves drink a healthy, but bad-tasting beverage (Baumeister et al., 2005). Participants who were excluded by being told no one in a group wanted to work with them ate more cookies in a taste-testing exercise than those who were told everyone in a group wanted to work with them (Baumeister et al., 2005). Excluded participants also persisted less on a frustrating task and performed worse on a dichotic listening task compared to non-excluded participants (Baumeister et al., 2005). Self-regulation is critical in overcoming one's impulses. Decreased ability to eat healthy foods despite their taste, as well as overcoming the desire to eat unhealthy foods and ignoring distractions, are prime examples of self-regulatory failure. Thus, these studies indicate that participants who have just experienced social exclusion are relatively more unwilling or unable to self-regulate effectively.

Perhaps due to these self-regulatory deficits, socially excluded people engage in a variety of self-defeating behaviors. Excluded participants, compared to non-excluded participants, were more likely to choose to participate in a relatively riskier lottery (i.e. one that had an overall lower net gain and in which losing also included listening to aversive noise; Twenge et al., 2002). Excluded participants were also more likely than their non-excluded counterparts to choose a variety of unhealthy over healthy behaviors. These included choosing to eat unhealthier foods, reading entertainment magazines instead of receiving feedback about their health, and opting to receive a resting versus running pulse measure (Twenge et al., 2002). Finally, excluded participants were more likely to procrastinate rather than prepare for an upcoming test, compared to non-excluded participants (Twenge et al., 2002). Following social exclusion, people are more likely to engage in behaviors that are contrary to their own interests.

3.3. Behavioral responses: Aggression versus altruism

Not only is social exclusion associated with self-defeating behavior, it is also associated with retaliation. Social exclusion is robustly associated with aggressive behavior (see Leary & Quinlivan, 2006 for a review). Excluded individuals, compared to their non-excluded counterparts, give more damagingly negative job candidate evaluations, make strangers listen to annoying tape recordings, blast strangers with more intense and prolonged noise, and dole out large amounts of hot sauce to people who express a strong dislike for spicy food. Excluded people act more aggressively not only toward their rejecters, but also towards members of a similar social group and even towards people completely unassociated with the rejecters (DeWall et al., 2010). The link between rejection and aggression also extends beyond the laboratory. Feeling rejected is one of the most common precipitating factors associated with domestic violence, in which men murder their wives (Barnard et al., 1982; Crawford & Gartner, 1992). Feeling rejected is also associated with aggression among women towards their husbands (Downey et al., 1998). Finally, there is some evidence that suggests school shootings are associated with social rejection (Leary et al., 2003). Across a variety of different situations both inside and outside a laboratory setting, rejection leads to aggression.

It does not always lead to aggression, however. When the target is the rejecter or when there is no hope for social reconnection, rejected people will act aggressively. In this case, there is no reason for excluded people to overcome their aggressive impulses. However, when it is possible to regain social acceptance, excluded people are motivated to act in a way that will regain their acceptance (see DeWall & Richman, 2011 for a review). Excluded participants, compared to non-excluded participants, awarded more money to a partner based on their partner's average drawing, even though doing so meant they were less likely to win the money back (Maner et al., 2007). This effect only held up if excluded participants expected to meet their partner (thus having the possibility of social reconnection.) If they did not, they had no motivation to behave prosocially and assigned less money to their partner than non-excluded participants did. Participants will behave prosocially in a group setting as well, if doing so can lead to social acceptance. Socially excluded participants, particularly those who were highly sensitive to rejection, ingratiated themselves by contributing more money to a group task than

non-excluded participants (Romero-Canyas et al., 2010). Socially excluded people will behave more prosocially if doing so can buy their acceptance.

3.4. Emotional responses

Thus far we know how social exclusion affects people both cognitively and behaviorally. Excluded people seem to experience a deficit in controlled processes and executive function as indicated by decreased cognitive performance and self-regulation as well as increased self-defeating behavior and aggression. One hypothesis for this effect is that exclusion causes emotional distress, which requires the use of cognitive resources to reduce its impact. Given what we know about the importance of belongingness (e.g. Baumeister & Leary, 1995), social exclusion should be a distressing and aversive experience. Thus after social exclusion, we would expect participants to report greater negative emotional states than accepted participants. However, empirical research shows that this is not the case. Socially excluded people often report emotional states that do not significantly differ from participants in acceptance or control conditions (Baumeister et al., 2002; Gardner et al., 2000; Twenge et al., 2001; Twenge & Campbell, 2003; Twenge et al., 2002; Zadro et al., 2004). Why are excluded participants numb to negative emotional distress?

One reason socially excluded people report numbness to negative emotional states may be that exclusion leads to a defensive state of cognitive deconstruction (DeWall & Baumeister, 2006). The deconstructed state (Baumeister, 1990) is characterized by emotional numbness, an altered perception of time, thoughts of meaninglessness, lethargy, and avoidance of self-focused attention. Socially excluded people show all of these behaviors (Twenge et al., 2003), suggesting that exclusion may bring about the deconstructed state. This deconstructed state may also explain the deficits in controlled processes as well as the increases in aggressive behavior exhibited by people who have been socially excluded. It may offer excluded people a temporary reprieve from feeling the intense pain or distress that can accompany threats to belongingness. However, after the reprieve, the social pain returns.

4. Overlap between social and physical pain

As we have hinted thus far, social and physical pain have much in common. Just as people experiencing social pain suffer deficits in self-regulation and executive functioning, so too do people experiencing physical pain suffer these same consequences. The similarities between the two types of pain extend beyond their consequences. Social and physical pain have numerous other psychological and physiological similarities. For this reason, we propose that severe social pain impacts the body in a similar way as physical injury.

4.1. Consequences of physical pain

The consequences of experiencing physical pain are very similar to those of experiencing social pain. People who are in physical pain, similar to people in social pain, experience deficits in

cognitive functioning and self-regulation as well as engage in a variety of self-defeating behaviors (for a review, see Solberg Nes et al., 2009). For example, just as people in social pain experience cognitive deficits that impair their logic and reasoning ability, so too do people in physical pain. In particular, chronic pain patients perform relatively worse on tasks that measure working and recognition memory, free recall, verbal fluency, and vocabulary (Landro et al., 1997; Park et al., 2001). Physical pain decreases cognitive functioning on a variety of tasks.

Additionally, similar to participants who are experiencing social pain, participants experiencing physical pain engage in more self-defeating behavior. For example, passive (e.g. relying on doctors, avoiding activities) instead of active (e.g. problem-solving, aiming to control pain) strategies of coping are less likely to help chronic pain patients (Callahan, 2000; Ferrando et al., 2004; Keefe et al., 1989; Snow-Turek et al., 1996; Zautra, 1999). Despite this knowledge, however, chronic pain patients are more likely to attempt to manage their pain through passive strategies (Callahan, 2000; Zautra, 1999). They are also less likely to engage in physical activity (Brown & Nicassio, 1987; Epker & Gatchel, 2000), another behavior that is encouraged and beneficial to the patients' recovery (Abel et al., 2005; Burckardt, 2002; Carlson et al., 2001; Nichols & Glenn, 1992; Smith et al., 2006). Thus, people experiencing chronic physical pain, just like people experiencing social pain, engage in behaviors that are contrary to their own interests.

4.2. Psychological similarities

Physical and social pain share several psychological and physiological similarities in addition to their shared consequences. For example, physical pain shares a linguistic similarity with social pain. People describing social pain use metaphors to physical pain such as "broken hearted," "emotionally scarred," or "crushed" (MacDonald & Leary, 2005). In the English language, not only do people describe social pain with reference to physical pain, but there is literally no way to describe it without making that reference (Leary & Springer, 2001). This linguistic link can be found across a wide variety of languages and cultures, including German, Hebrew, Mandarin, and Inuktitut, as well as at least 10 others. (MacDonald & Leary, 2005). Although the linguistic similarity between social and physical pain does not give direct proof of an overlap between their mechanisms, it does show that people think of social and physical pain in extremely similar ways. If social and physical pain share a common psychological or physiological basis, there should be evidence of a crossover between the two types of pain. Specifically, more extreme physical pain should be associated with increased sensitivity to social pain and vice versa. Indeed, the similarity goes beyond mere metaphor.

Personality traits related to a fear of social pain are also associated with pain tolerance, giving further evidence to a relationship between physical and social pain. Introverts, people who are overall less social and more afraid of rejection, have a lower pain tolerance than extraverts, people who are overall more social and less afraid of rejection (Phillips & Gatchel, 2000). This research demonstrates that people who have a lower tolerance for social pain also have a lower tolerance for physical pain. The connection between fear of social pain and pain tolerance is known to work in the opposite direction as well. Increased physical pain, such as chronic pain sufferers experience over time, is associated with behaviors indicative of a fear of social pain.

Chronic pain sufferers become more introverted, socially anxious, and avoidant of social situations the longer their chronic pain continues (Phillips & Gatchel, 2000; Sharp & Harvey, 2001). As people continue to experience physical pain, they become increasingly averse to social pain. These findings show a clear link between physical and social pain. They support the idea that both physical and social pain are managed by the same psychological and physiological systems.

4.3. Physiological similarities

Evidence for physiological overlap in physical and social pain stems from the early work of Panksepp and colleagues (Herman & Panksepp, 1978; Panksepp et al., 1978; Panksepp et al, 1978). They noticed the many similarities between the two types of pain and proposed an evolutionary explanation. They hypothesized that the link between social and physical pain exists because evolution piggybacked these neurological systems on top of each other. Animals needed to adapt to increasing social interaction and instead of creating an entirely new system for doing so, evolution used an already existing one. It piggybacked responses to social pain onto the existing systems hard-wired to respond to physical pain. The result of these shared systems is that social events will activate the body's pain response system and possibly have repercussions on how it registers physical pain. This explanation would account for the similarities we have discussed so far, but what evidence do we have for it?

Psychobiological research supports this evolutionary theory and indicates at least two such systems that respond to both physical and social pain. The periaqueductal gray (PAG) brain structures, which receive input from the body's injury detection system (nociceptive system), and anterior cingulated cortex (ACC) are involved in both the detection of physical pain and in animal bonding behavior (Craig & Dostrovsky, 1999). Activation of the PAG elicits separation distress cries from rats (Panksepp, 1998) and lesions to this area lead to reduced separation distress cries (Wiedenmayer et al., 2000). Young rats detect separation from their mother, an occurrence that is socially painful, by means of the same system that detects physical injury. Similarly, lesioning the cingulate eliminates separation distress in hamsters and squirrel monkeys (Maclean & Newman, 1988; Murphy et al., 1981). Administration of oxytocin and opiods such as morphine, used to diminish physical pain, also lead to reduced social pain in the form of reduced separation distress cries in rats (Carden et al., 1996; Carden & Hofer, 1990; Insel & Winslow, 1991). Pharmacological physical pain relief soothes distressed young rats that have been separated from their mothers. These findings indicate that the PAG and ACC are systems that respond to both physical and social pain.

Additional evidence for the overlap between physical and social pain mechanisms stems from research showing that physical pain can be alleviated by social support. Social support, which alleviates social pain, also alleviates physical pain across a variety of situations. Increased social support is associated with reduced chronic pain (Phillips & Gatchel, 2000), labor pain (Klaus et al., 1986; Niven, 1985), cardiac pain (Chalmers et al., 1995; Cogan & Spinnato, 1988), and postoperative pain (Lidderdale & Walsh, 1998). The link between physical pain and social support has also been demonstrated experimentally, which showed that participants had a higher pain threshold, as measured by the cold pressor task (i.e., participants immersed one

hand into a container of ice cold water and kept it there until they could no longer tolerate it) when social support was applied before the experience (Brown et al., 2003). Social support can buffer both physical and social pain. This suggests that social and physical pain share many of the same psychological and physiological mechanisms.

4.4. Social pain causes physical numbness

Experimental evidence gives further support to the shared mechanisms between the physical and social pain systems. While social support alleviates physical pain, social pain results in physical numbness. That is, socially painful events can have an analgesic effect (i.e., decreased sensitivity to physical pain). As we mentioned earlier, humans experience emotional numbness following social exclusion in the lab (e.g. Baumeister et al., 2002). A similar phenomena is also found among nonhuman animals. Isolation, a phenomenon that is associated with social pain, produces reduced sensitivity to physical pain in rat pups (Kehoe & Blass, 1986a, 1986b; Naranjo & Fuentes, 1985; Spear et al., 1985), mice (Konecka & Sroczynska, 1990), cows (Rushen et al., 1999), and chicks (Sufka & Hughes, 1990; Sufka & Weed, 1994).

Recent research shows that exclusion also produces insensitivity to physical and emotional pain in people. Participants who were told they would end up alone later in life, compared to those who were told they would have lots of friends or those who were told they would be accident-prone, showed significantly higher pain thresholds as evidenced by resisting greater amounts of pressure from a pressure algometer (DeWall & Baumeister, 2006). Exclusion also affected emotional forecasting, simulating emotional responses to possible future events. Excluded participants, compared to those in the two control conditions, predicted relatively neutral emotional reactions to their college football game winning and losing against a rival team (DeWall & Baumeister, 2006). Excluded participants also exhibited significantly less empathy for a person experiencing social pain compared to participants in either control condition. Importantly, increased pain threshold and tolerance scores were a significant predictor of empathy scores. Thus, the increased threshold and tolerance for physical pain following exclusion was related to lack of empathic concern for others. These results were replicated for feeling empathy toward a person in physical pain as well (DeWall & Baumeister, 2006). Next we will introduce the neuroscientific approach to the study of social rejection, reviewing research that has used functional magnetic resonance imaging to help uncover the neural similarities between social and physical pain.

5. Neuroscience and social rejection

While the use of a biologically-based approach to understand social-psychological processes can be dated to Ancient Greece and Galen's four humours, neuroscience has only been substantially used to investigate this topic in the past decade or so (Lieberman, 2007). In this time, we have seen a diminished viewpoint among scholars that looking at the brain to understand the complex world of human social dynamics is an irredeemably reductionist endeavor, as well as the emergence of the field of social neuroscience (a.k.a. social cognitive neuroscience) replete with its own dedicated organizations, conferences and journals (see

Harmon-Jones & Winkielman, 2007). As testament to this exponential growth, the number of PsycINFO database hits that return from a search of the term *social neuroscience* have multiplied by an order of more than 16 from 2000 to 2007 (Harris, 2009). Functional magnetic resonance imaging (hereafter fMRI) has been at the forefront of the charge in this neuroscientific revolution of social psychology, providing an unobtrusive avenue through which to elucidate the human mind by measuring the hemodynamic functions of the brain.

As social neuroscience has burgeoned over the past 10-15 years, so has research on social rejection. As we have shown so far in this chapter, conventional methodologies such as overt behavior and self-report have dominated this area of inquiry and have revealed a dizzying amount of information about the powerful and dynamic nature of social rejection. However, as social phenomena are increasingly placed under the lens of investigators using neuroimaging techniques, the literature on social rejection has become infused with a wealth of brain research, though often from researchers without that goal in mind. For instance, Roy Baumeister and Mark Leary's Belongingness Hypothesis (1995), which posits that humans are consummately social beings that require social bonds in the similarly urgent way that they require food and water, was unintentionally substantiated by cognitive neuroscientists who found that the default mode network's regions (i.e., dorsomedial prefrontal cortex, medial prefrontal cortex, ventromedial prefrontal cortex, precuneus, the tempoparietal junction, fusiform gyrus, and temporal poles) are strikingly similar to those involved in social cognition (for a review see Lieberman, 2010). For instance, these areas are crucial for making sense of other people's minds (i.e., mentalizing), for empathizing with others and making moral judgments, as well as for reflecting and forming knowledge about the self (Lieberman, 2010). Thus, when people are not doing other tasks, they engage in thoughts about themselves and their social relationships. Only a remarkably social species would have evolved a brain which, given a lack of external preoccupation, 'prefers' to engage in socially-relevant mental activity. Additional fMRI studies revealed that activation in the ventral striatum, a brain region associated with the feeling of reward, was associated with positive social feedback about oneself (Izuma et al., 2008) and altruistic helping of others (Moll et al., 2006). Demonstrating such a pervasive social-preoccupation and prosocial-orientation of the human brain implicates social rejection as one of the largest threats to our well-being.

Aside from the neuroscience studies that have incidentally advanced the field of social rejection research, relatively few studies have focused explicitly on the topic. Importantly, these studies have garnered a colossal degree of interest (and controversy) from the scientific community and the general populace. For example, the first published fMRI study on social rejection (Eisenberger et al., 2003) has been cited over 400 times in less than eight years. Later in this chapter, we will go into detail about several of these experiments, but beforehand we would like to discuss the features of functional neuroimaging that have made them so impactful.

6. Advantages of functional neuroimaging in social rejection research

Given that social rejection research has flourished with the use of conventional measurements such as self-report, overt behavior, and response-time, why should any researcher

opt to use neuroimaging techniques in this line of investigation (or any other for that matter)? We argue that functional neuroimaging, fMRI in particular, is a necessary toolbox to fully understand complex social processes, given a laundry list of beneficial attributes that are not available through conventional methodologies. As a most evident benefit, neuroimaging data is not confounded by the psychometric imprecision that is often commensurate with self-report and certain behavioral measures such as response bias and introspective inaccuracy. Additionally, neuroimaging techniques allow researchers to meaningfully distinguish and associate psychological processes on the virtue of whether they are associated with similar or dissimilar neural regions (Lieberman, 2007). Neuroimaging alone can determine when two psychological processes reflect *different* neural mechanisms despite being experientially *similar*, or conversely, when two psychological processes reflect *similar* neural mechanisms despite being perceived as *different*. As an example of the latter capability of fMRI, the medial prefrontal cortex activates similarly to judgments that focus on the self and other individuals who have close relationships with us (Mitchell et al., 2006). By associating or disassociating such mental states, we can further our understanding of the dynamic interactions in the mind and how the brain's structure influences the expression of our thoughts, feelings and behavior. Furthermore, by describing psychological mechanisms in terms of their neural correlates, neuroimaging replaces the often abstract and subjective definitions produced by conventional methods with more objective delineations. Instead of referring to an arbitrarily-defined cognitive sub-mechanism (e.g., the visuospatial sketchpad), we can discuss the neuroanatomical region(s) that process is associated with, its size and position in the brain, the connections that region has to other brain areas and the effects which those connections have (i.e., inhibitory, excitatory). By doing so, psychologists and neuroscientists alike ground models of the mind in concrete parameters that are readily translatable to other fields such as medical and biological sciences. Not only can neuroimaging data help with advances in medical and pharmacological treatments, but can also serve as the basis for understanding behavioral processes, as a result of the novel hypotheses generated via the fMRI technology, which elucidates physiological underpinnings. These powerful advantages of functional neuroimaging are the forces driving the productivity and quality of fMRI research on social rejection.

7. Exemplary fMRI studies on social rejection

Now we will focus on four of the aforementioned advantages of adopting neuroimaging methodologies. Each advantage will be accompanied by an fMRI study on social rejection that exemplifies it. It is our hope that in this section we will demonstrate that social rejection research is a line of inquiry that has substantially benefited from the use of fMRI techniques and that these material gains argue for the necessity of functional neuroimaging to understand complex social phenomena. Summary information for each study can be found below in Figure 1 and in Table 1.
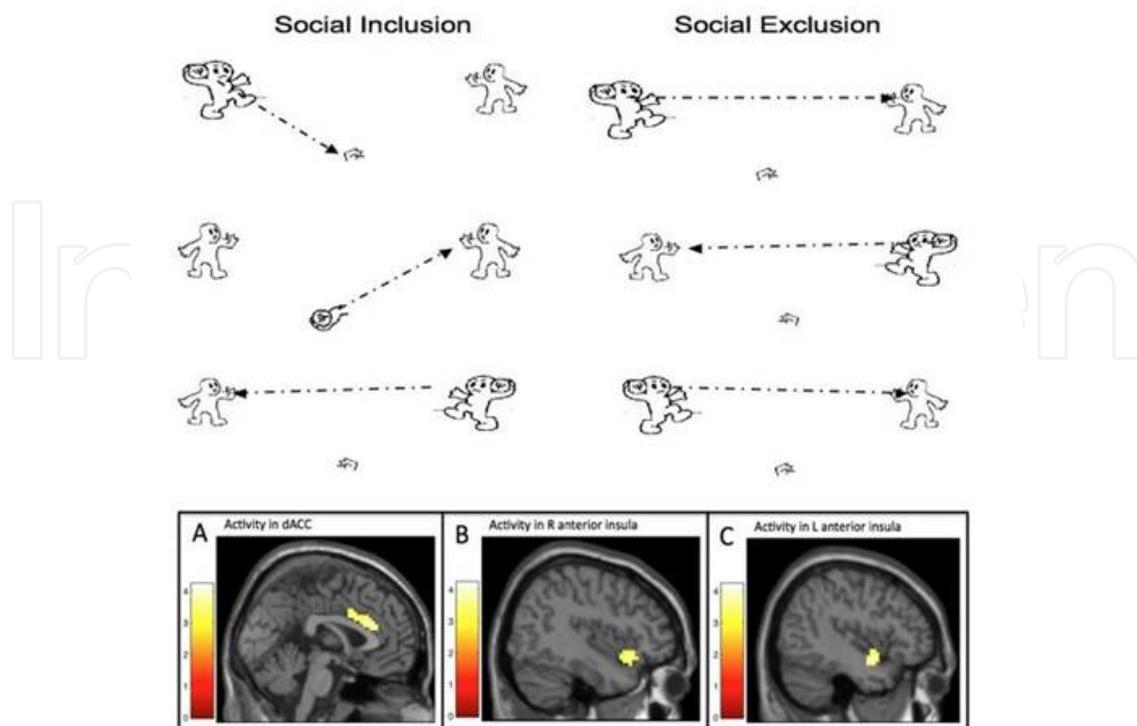
Figure 1. The top represents example stimuli from the Cyberball game used in fMRI research on social rejection. Participants typically play the inclusion round during the first scan and the exclusion round during the second scan. The bottom shows areas in the brain that are associated with the affective component of pain (i.e., dACC and anterior insula) which also become activated during exclusion (vs. inclusion) in the Cyberball paradigm.

Study:	Paradigm:	Analysis of Interest:	Regions of Interest:
Eisenberger et al., 2003	Cyberball paradigm: 1st scan = included 50% of time 2nd scan = excluded after 7 throws	Whole-brain analysis: Exclusion vs. Inclusion	dACC, RVPFC
Eisenberger et al., 2007	Cyberball paradigm: 1st scan = included 50% of time 2nd scan = excluded after 7 throws	Region of interest regressions with: Daily social support, Cortisol reactivity, Distress	dACC, DSFG
DeWall et al., 2010	Cyberball paradigm: 1st scan = included 33% of time 2nd scan = excluded after 3 throws	Region of interest regression with: Tylenol condition	dACC, anterior insula, amygdala
Masten et al., 2011	Cyberball paradigm: 1st scan = included 33% of time 2nd scan = excluded after 10 throws	Region of interest regression with: Observer ratings of distress, Attributions of discrimination, Self-reported distress	dACC, anterior insula

Table 1. Summary of the studies presented in Section 7. Neural activity of interest is during exclusion vs. inclusion.

7.1. Associating seemingly-distinct psychological processes based on shared neural substrates: Eisenberger et al., 2003

Naomi Eisenberger and her colleagues (2003) were not only the first researchers to report fMRI findings on social rejection, but their results confirmed a striking hypothesis that social injury elicits a nearly identical neural response as harm to one's *soma*. To achieve these results, they adapted a computerized, ball-tossing task (Cyberball: Williams et al., 2000) to the fMRI environment that immersed participants in experiences of social acceptance and rejection. Participants were told that they would play a virtual ball-tossing game inside the scanner, via the Internet, with two other participants who were also in scanners. In reality, computer programs represented the other players. During the first round of the game, participants were included (i.e., received a ball toss from one of the virtual players) throughout the round. However, during the second round, the virtual players stopped throwing the participant the ball after he or she had received three throws. Participants were excluded for the remainder of the game and watched as the two virtual players continued without them. After the scanning procedures, participants reported the degree of social distress (a facet of social pain) they experienced due to the rejection manipulation. Traditionally, the neurological mechanisms of pain have been separated into three components: 1. the sensory component, 2. the affective-motivational component, and 3. the evaluative component (Melzack & Casey, 1968). In their study, Eisenberger and colleagues (2003) discovered neural activation that was specific to social rejection in three brain regions previously associated with the affective component of physical pain (e.g., Bush et al., 2000; Carter et al., 2000; Foltz & White, 1968; Lieberman et al., 2007; Price, 2000; Rainville et al., 1997). One of these regions was the dorsal portion of the anterior cingulate cortex (hereafter dACC), a key region for the affective component of pain (see Apkarian et al., 2005 for a review), which is often conceptualized as an 'alarm system' that monitors the external environment for elements that deviate from the ideal (Bush et al., 2000; Carter et al., 2000). It then responds by eliciting feelings of distress that motivate the individual to repair or assuage the discrepancy (see Eisenberger & Lieberman, 2004). The second region was the anterior portion of the insula, a cortical structure previously associated with both negative affect (e.g., Lane et al., 1997) and visceral pain (e.g., Aziz et al., 2000). Last, this study reported activation in two voxel-clusters of the right-ventral prefrontal cortex (hereafter RVPFC), an area of the neocortex which functions to regulate aversive experiences (e.g., Petrovic & Ingvar, 2002). As predicted, activation in the dACC predicted *greater* levels of social distress, while conversely, the RVPFC predicted *lesser* amounts of social distress. DACC activation also mediated the inhibitory relationship between the RVPFC and social distress, suggesting that the RVPFC reduces subjective distress to social threat by inhibiting the dACC response to it. Taken together, these results are astoundingly analogous to those from physical pain research (e.g., Foltze & White, 1968; Kong et al., 2006; Petrovic et al., 2005; Rainville et al., 1997), establishing the functional similarity between physical and social pain, which has great implications for the understanding and treatment of various psychopathologies, such as post-traumatic stress disorder (PTSD; Felmingham et al., 2007) and anxiety (Simmons et al., 2008). Perhaps most importantly,

these findings suggest that maintaining social connections should be conceptualized as a fundamental human need, to the same degree as physical safety, since evolution has given the two equal standing as evidenced by the same neural underpinnings.

The Eisenberger and colleagues (2003) study is exemplary in another related way, in that it largely resolved a decades-long line of research that was previously relegated to harmful experiments on nonhuman animals. Various researchers have suspected the possible social/ physical pain overlap that we have discussed here in detail, but since functional neuroimaging techniques were not yet available, their research has taken such forms as measuring the distress vocalizations of socially-isolated bird chicks (Panksepp et al., 1978) and ablating the cingulate cortex of squirrel monkeys (MacLean & Newman, 1988). Thanks to fMRI, it is no longer necessary for a great deal of research questions to be performed on nonhuman animals, who contribute results that are not always readily translatable to humankind and who are often harmed in the process.

7.2. Translating psychological processes to their biological mechanisms: Eisenberger et al., 2007

While research on social rejection and isolation had established that a prolonged lack of interpersonal connections is extremely deleterious to physical and mental health (e.g., House et al., 1988; Berkman & Syme, 2007), the biological mechanisms through which this process occurred was largely unknown. Capitalizing on the unique ability of neuroimaging to lay bare the brain's response to social rejection in a format which could then be statistically assessed in relation to other biological processes, Naomi Eisenberger and her colleagues (2007) pitted two popular hypotheses of how social connections improve health outcomes against one another. In these hypotheses, which are not necessarily mutually exclusive, social bonds:

a. lessen the extent to which events are perceived as threatening via reduced activation in brain regions associated with HPA activation (namely the dACC, amygdala and insula).

and/or

b. increase the coping resources an individual can apply to a threat via greater activation of 'top-down' brain regions associated with self-regulation (namely the ventrolateral- and medial-prefrontal cortices).

Both of these postulated mechanisms would down-regulate the hypothalamic-pituitary-adrenal axis (hereafter HPA axis) response to threats, the activation of which releases the stress hormone, cortisol, into the bloodstream (i.e., cortisol reactivity). Since cortisol suppresses the immune system, both of the aforementioned explanations would ultimately protect individuals by preventing the reduced immune-function that is commensurate with the physiological stress response. To test these competing theories, participants had endogenous cortisol measurements taken before and after a stress-inducing task, with increases in cortisol over the course of the stressful task indicating a larger degree of cortisol reactivity. Self-reported social distress was recorded from each participant immediately after the stress task as well. Over the following 10 days, participants reported the degree of social support they felt at various times

throughout that period. At the end of the 10 days, participants had fMRI scans taken of their brain while they performed a variant of the ball-tossing task described in the Eisenberger et al., 2003 study which manipulated experiences of social acceptance and rejection. The authors of the study planned to assess the degree to which neural responses to social rejection were associated with social support, cortisol reactivity during the stress task, and self-reported social distress. The results yielded no support for the hypothesis that social support increases activation in brain regions that would facilitate coping with stressful events, since no neural regions were activated above statistical threshold in the acceptance condition. However, regression analyses on the rejection condition revealed there was substantial evidence for the hypothesis that social support improves physical health by reducing activation in brain regions associated with social distress/pain. Specifically, activation during social rejection in both an *a priori* region-of-interest analysis of the dACC and Brodmann's Area 8 of the dorsal superior frontal gyrus (hereafter DSFG) were both *negatively* correlated with social support and *positively* correlated with both social distress and cortisol reactivity. Rejection-specific activation in both the dACC and DSFG mediated the inhibitory relationship between social support and cortisol reactivity, which implicates these two regions as the mechanism through which social support reduces the physiological stress response. Moreover, rejection-specific activation in the hypothalamus mediated the relationships between the dACC and DSFG and cortisol reactivity. This suggests that the dACC and DSFG influence stress responses by modulating the activity of the HPA axis. Summarizing these findings, this study supports the claim that when people encounter a social threat (e.g., public speaking, social rejection), their everyday levels of social support reduce activation in both the dACC and DSFG. Reduced activation in the dACC and DSFG subsequently reduces HPA axis activation, cortisol release and suppression of the immune system. Aside from the clear implications these findings have for treatments and therapies, this study is a prime example of the process through which functional neuroimaging allows for a more objective delineation of a behavioral response into its physiological components.

7.3. Generating novel hypotheses based on physiological principles: DeWall et al., 2010

Recent work from our lab stands as a clear example of the ability of fMRI to produce novel psychological hypotheses based purely on physiological knowledge of neural correlates. Since previous research had established the overlap between brain regions involved in social and physical pain (e.g., Eisenberger et al., 2003), DeWall and colleagues (2010) tested whether a popular physical-pain-reliever, acetaminophen, would have similar analgesic effects for social pain. In the first study, twice-daily ingestion of acetaminophen (compared to placebo) reduced self-reported social pain over a time period of three weeks. To assess whether these self-reports translated to diminished pain responses in the brain, participants who had either taken acetaminophen or placebo twice-daily for three weeks (same as study 1) were placed in an fMRI scanner and then socially-accepted and -rejected by a similar version of the computerized, ball-tossing task used in the two previous studies.

Participants who had taken acetaminophen showed reduced activation (as compared to those who took placebo) during rejection (as compared to acceptance) in both brain regions previ-

ously associated with social pain, the dACC and anterior insula. Participants who took acetaminophen also showed lesser activation of the amygdala during social-rejection, a brain region involved in producing 'fight-or-flight' responses. By understanding the physiological similarities between social and physical pain, a novel hypothesis was vetted about a psychological process with powerful implications for our understanding and treatment of social rejection.

7.4. Covert measurement of social processes that avoid self-report biases: Masten et al., 2011

Much of the phenomena that interest social psychologists are sensitive to issues of self-presentation and demand characteristics. Thus, psychologists favor measurement tools that avoid or are at least robust to these self-report biases. For example, psychologists interested in studying prejudice may opt for measuring implicit attitudes of their participants, because people may not respond truthfully on self-report questionnaires if holding racist attitudes is looked down upon socially. The fMRI scanner represents a powerful tool that can be used to assess such attitudes in a way that is not subject to self-report biases. A recent rejection study conducted by Masten and colleagues (2011) is an excellent example for how neuroimaging can be utilized to investigate potentially sensitive topics. Specifically, they investigated the neural correlates of negative social treatment associated with racial discrimination.

In their study, African American participants encountered two white (1 male, 1 female) confederates during the informed consent procedure. The participants were told that they would be playing a virtual ball-tossing game (i.e., Cyberball) with the two confederates, while they were each inside fMRI scanners. In reality, participants played the virtual ball-tossing game with a preprogrammed computer. During the initial scan, participants were included by their virtual partners, who threw the ball to the participant one third of the time. However, during the second scan, participants were excluded from their partners after receiving ten throws. After the scanning session, participants completed self-report measures of distress and discriminatory attributions. Observers also rated the participants' level of distress during videotaped interviews, in which the participants discussed their feelings about being excluded during the game.

Using a whole-brain analyses approach, Masten and colleagues (2011) found that exclusion (vs. inclusion) increased activity in the anterior insula, and rACC, and decreased activity in the VLPFC, which was consistent with previous research (Eisenberger et al., 2003, 2007). Yet, in region of interest analyses, self-reported distress was not related to activation in these areas during exclusion, as previous research would suggest. However, observer-rated distress was related to increased activity in the dACC and anterior insula and decreased activity in the VLPFC and ALPFC, which is consistent with previous research. These findings highlight the robustness of fMRI procedures to self-report biases. Last, the authors found that the more participants attributed the exclusion experience to racism, the less activation they experienced in the dACC during exclusion. This last finding suggests that attributing negative social events to discrimination provides a protective function, which allows the individual to better cope with the distress.

8. Individual difference factors that moderate neural responses to social rejection

In the previous sections of this chapter, we described how most everyone desires at least some level of social acceptance and that experiences of rejection can have very powerful physical and psychological consequences. We described how the use of fMRI methodologies have helped social psychologists identify the shared neural substrates of physical and social pain, and how this tool has helped psychologists generate and test novel hypotheses about the physiological processes that underlie social pain. In this final section, we will discuss recent research from our lab, which utilized fMRI procedures to identify those individuals who are most vulnerable to social rejection. Specifically, we will concentrate on two individual difference factors that modulate neural responses to rejection, namely one's level of attachment anxiety and one's capacity for identifying and describing emotional experiences. People who are high in attachment anxiety possess an intense desire for intimacy and are highly sensitive to the potential for rejection (Fraley & Shaver, 2000). Thus, they may exhibit heightened neural responses to rejection, compared to individuals who are less anxiously attached. Similarly, people who have a low capacity for identifying and describing their emotional experiences may show heightened neural responses to rejection, because they respond more negatively to stressful situations than people who have a greater capacity for describing their emotions (Barrett et al, 2004; Kashdan et al., 2010; Tugade et al., 2004). Table 2 below presents a brief summary of the two studies that will be described in more detail in sections 8.1 and 8.2

Study:	Paradigm:	Analysis of Interest:	Regions of Interest:
DeWall et al., 2011a	Cyberball paradigm: 1st scan = included 33% of time 2nd scan = excluded after 3 throws	Region of interest regressions with: Anxious attachment, Avoidant attachment	dACC, anterior insula
DeWall et al., 2011b	Cyberball paradigm: 1st scan = included 33% of time 2nd scan = excluded after 3 throws	Region of interest regressions with: Emotional differentiation X Self-esteem	dACC, anterior insula

Table 2. Summary of studies presented in Section 8. Neural activity of interest is during exclusion vs. inclusion trials.

8.1. Neural responses to rejection depend on attachment style

Prior work has shown that belongingness threats can cause a variety of negative emotional, cognitive, and behavioral outcomes (e.g., Baumeister et al., 2002; DeWall et al., 2009; Twenge et al., 2001, 2003), and that these threats activate some of the same neural substrates as those underlying physical pain (Eisenberger et al., 2003). However, people vary a great deal in how they experience and maintain social relationships. For example, some people may have a high need for social acceptance and are especially attuned to signs of rejection, whereas others may

be uncomfortable with close relationships. Such differences in attachment style may have direct implications for neural responses to experiences of rejection.

DeWall and colleagues (2011) tested whether individual differences in anxious and avoidant attachment styles moderated neural responses to social rejection. They predicted that people with high attachment anxiety (depicted as having a great desire for closeness and vigilant to rejection cues; see Fraley & Shaver, 2000) would show heightened neural activity in those regions associated with the processing of social rejection (i.e., dACC and anterior insula). On the other hand, they predicted that those individuals who demonstrated a high level of avoidant attachment (depicted as being uncomfortable with closeness and uses regulatory strategies to minimize attention to attachment-related events and information) would show dampened activity within those same neural regions. In their study, participants completed the Attachment Style Questionnaire (ASQ; Feeney et al., 1994) in the lab, and then returned three weeks later to complete a virtual ball-tossing game in an fMRI scanner. Following Eisenberger and colleagues' (2003, 2007) and DeWall and colleagues' (2010) procedures (i.e., the Cyberball paradigm), participants believed that they were playing the virtual ball-tossing game with two other participants already in fMRI scanners. In reality, computer programs represented the other players. During the first scan, the virtual players regularly tossed the ball to the participants. However, during the second scan, the virtual players excluded those participants who received three throws. After playing the ball-tossing game, participants completed a measure of social distress.

As predicted by DeWall and colleagues (2011), participants with a high level of attachment anxiety exhibited more activity in the dACC and anterior insula while experiencing social exclusion (vs. social inclusion). These results suggest that anxious attachment is associated with greater negative responses to belongingness threats. On the other hand, a high level of avoidant attachment was related to less activation within the dACC and anterior insula during social exclusion (vs. social inclusion). These results suggest that people who reflect the avoidant attachment style detach from attachment-relevant situations, thereby providing a buffer to the negative effects of potential rejection. These findings support and extend prior work on the pain of social rejection. Moreover, they demonstrate how neuroimaging methodologies can be used to allow social psychologists a better understanding of how personality characteristics moderate physiological responses to social situations.

8.2. Self-esteem and level of emotional differentiation interact to predict neural responses to rejection

Attachment style represents just one factor that can increase or decrease one's vulnerability to social threats. However, there are surely many other personality characteristics that can intensify or buffer the negative effects of rejection. Self-esteem is one potential factor that has garnered recent attention from social psychologists. People who generally perceive that others reject them tend to have low self-esteem. In contrast, people who generally perceive acceptance from others tend to have high self-esteem (Leary et al., 1995). Using a similar virtual ball-tossing paradigm as the studies above, Onoda and colleagues (2010) have provided some of the first evidence from neuroimaging that people with low self-esteem experience more distress during

rejection than people high in self-esteem. They showed that people with low self-esteem exhibit greater activation within the dACC during a simulated rejection experience (vs. inclusion). Similarly, using a social evaluative task, Somerville and colleagues (2010) demonstrated that people with low self-esteem exhibited greater activation in a more ventral area of the anterior cingulate cortex after receiving negative social feedback (versus positive social feedback).
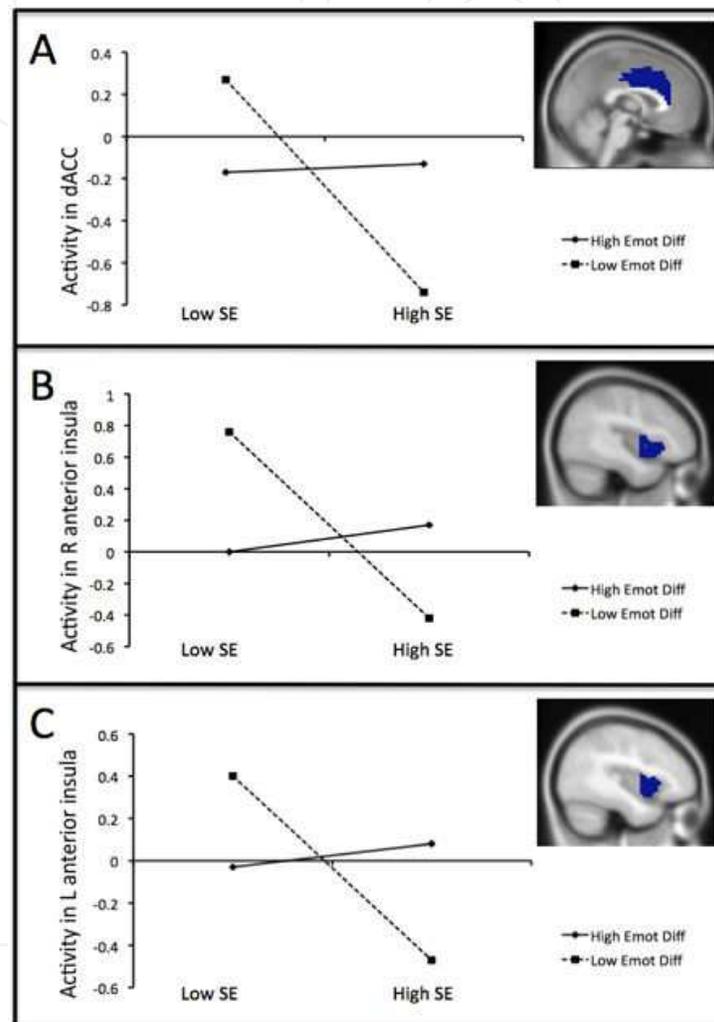

Figure 2. Neural activity during exclusion (vs. inclusion) within the dACC (Panel A) and anterior insula (Panels B & C) as a function of self-esteem and emotion differentiation (based on a priori anatomically-defined ROI analyses; significance was defined as p < .05). The functionally-defined ROI's are depicted in blue.

Following the work of Onoda and colleagues (2010) and Somerville and colleagues (2010), DeWall and coauthors (2011) explored whether one's capacity for identifying and describing emotional experiences (i.e., emotional differentiation) moderated the effects of self-esteem on neural responses to social rejection. People who are better at differentiating their emotional experiences respond more positively to stress and depend less on maladaptive coping strategies, such as abusing alcohol (Barrett et al, 2004; Kashdan et al., 2010; Tugade et al., 2004). On the other hand, people who are less able to identify and differentiate their emotional

experiences react more negatively to stress, possess more negative attitudes, and are more likely to use those maladaptive coping strategies. Thus, DeWall and colleagues (2011) predicted that greater emotional differentiation should be linked to psychological resilience to social rejection experiences. However, among individuals who exhibit a lower capacity for emotional differentiation, those with low self-esteem will be most vulnerable to experiences of rejection, which will be evidenced in heightened responses in the dACC and anterior insula.

In DeWall and colleagues' (2011) study, participants completed daily diary measures of self-esteem and negative emotion for a three-week assessment period. After the diary portion of the study, participants completed the virtual ball-tossing game (i.e., the Cyberball paradigm) with two ostensible partners while in an fMRI scanner (first scan = inclusion round, second scan = exclusion round). Last, participants completed a measure of social distress. All neuroimaging data were preprocessed and analyzed using Statistical Parametric Mapping (SPM8; Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). As with the study described in section 8.1, anatomically-defined region of interest (ROI) analyses were implemented based on a priori hypotheses regarding the involvement of the dACC and anterior insula in processing social rejection. Differential activity in each ROI during exclusion vs inclusion was examined, as well as how this activity related to individuals' self-esteem, emotion differentiation, and the interaction between self-esteem and emotion differentiation (significance was defined as $p < .05$). Parameter estimates of activity during exclusion vs inclusion were entered as dependent variables in hierarchical multiple regression analyses, with self-esteem and emotion differentiation scores entered as predictors in the first step and their interaction entered as a predictor in the second step. Finally, supplemental whole-brain analyses were implemented, thresholded at $p < .005$ and 20 voxels for a priori defined regions of interest, while all other regions were examined at a threshold corrected for false discovery rate.

As predicted, regression analyses showed that among low emotional differentiators, lower self-esteem was strongly associated with greater activation in the dACC and the anterior insula during exclusion (vs. inclusion). However, high emotional differentiation bore no relation to activity in these neural regions during exclusion (vs. inclusion), regardless of selfesteem level (see Figure 2). These findings extend prior neuroimaging research linking low self-esteem to increased vulnerability to social rejection, by demonstrating that one's level of emotional differentiation may reinforce or buffer this relationship. Additionally, this research is an example of how neuroimaging can be utilized to explore the physiology of psychological resilience and expand upon prior conclusions drawn from behavioral and/or self-report methodologies.

9. Criticisms of the Cyberball paradigm

For the most part, the fMRI literature on social rejection is nested within the Cyberball paradigm (Williams et al., 2000), in which participants believe that they are playing a ball-tossing computer game over the Internet with two other participants who are, ostensibly, also

in MRI scanners. However, the nature of the rejection experience during Cyberball is not without its limitations. For example, in order for the rejection manipulation to maintain believability and ecological validity, all participants are included by their virtual partners during the first fMRI scan and excluded by those same partners during the second scan. The blocks must be presented in this order to ensure that all participants have the same expectations from one scan to the next. That is, if the blocks were presented randomly, then those participants who encountered exclusion during the first scan would naturally expect exclusion on the second scan. Inclusion during the second scan might appear unrealistic.

Although the presentation of inclusion blocks and exclusion blocks are not usually randomized in the Cyberball paradigm, follow-up fMRI research has replicated the patterns of brain activation commonly reported with Cyberball, using other manipulations of rejection. For example, participants show increased activity within the dorsal ACC while viewing rejection-themed images as opposed to acceptance-themed images or abstract paintings of positive and negative valence (Kross et al., 2007). Similarly, people show increased dACC activity while viewing pictures with disapproving facial expressions (Burklund et al., 2007). Moreover, Sebastian and colleagues (2010) found that activation within the amygdala and subgenual ACC increased when participants viewed social threat words (e.g., pathetic), as opposed to neutral words, during a rejection-themed emotional Stroop task. They also found an Age x Valence interaction, such that adults who viewed rejection-themed words, in contrast to acceptance or neutral control words, exhibited decreased activity within the right VLPFC. However, this activity was not present in adolescents who viewed the rejection-themed words. This finding suggests that maturation of the right VLPFC, an area associated with affect regulation, continues during adolescence. Last, a recent study conducted by Bolling and colleagues (2011) actually modified the Cyberball paradigm, such that participants played several blocks of the game, which alternated between inclusion and exclusion. They found that participants' self-reported distress after Cyberball was comparable to previous research and did not decline or become less upsetting over time. Additionally, the authors replicated previous research by showing, in whole-brain and region of interest analyses, that brain activity within the ventral anterior cingulate cortex (vACC), the posterior cingulate cortex (PCC), and the right anterior insula increased during exclusion (vs. inclusion). Each of these studies give support for the validity of the Cyberball paradigm for fMRI research.

Another criticism of the Cyberball paradigm for fMRI research is that the manipulation may not be strong enough to mimic the sensation of physical pain, nor is it especially prolonged. Thus, experiences of intense social pain that are drawn out over time may prove to be more beneficial in examining the neural similarities between physical and social pain. For example, a recent study by Kross and colleagues (2011) shows that the overlap between social and physical pain may be more extensive than previously understood. They argued that neural activation during social pain should not just mirror the affective component of physical pain (e.g., activation within the dACC and anterior insula), but if the socially painful experience is extreme enough then it should also mirror the sensory component of physical pain (e.g., activation within the secondary somato-sensory cortex and the dorsal posterior insula). In their study, they recruited participants who have recently experienced an unwanted romantic

break-up. Those participants then performed two counterbalanced tasks during an fMRI scanning session: 1. a Social Rejection task, and 2. a Physical Pain task. During the rejection-trials of the social rejection task, participants viewed a headshot of their ex-partner and thought about their specific break-up. During friend-trials of the social rejection task, participants viewed a headshot of a close friend of the same sex as the ex-partner and thought of a positive experience with that friend. During the physical pain task, participants experienced painfully hot thermal stimulation to an area on their left arm during hot trials and non-noxious thermal stimulation to the same area during warm trials. In a whole-brain conjunction analyses and region of interest analyses, the authors found that the brain activation during social rejection overlapped with the brain activation during physical pain in the areas associated with the affective component of pain (i.e., dACC and anterior insula), replicating previous research (e.g., Eisenberger et al., 2003). Moreover, the brain activation during social rejection also overlapped with the brain activation during physical pain in areas associated with the sensory component of pain (i.e., the thalamus and the secondary somatosensory cortex). Thus, one of the implications of this research is that to fully understand the overlap between physical and social pain, researchers must employ stronger manipulations of rejection than what the Cyberball paradigm might provide.

10. Future directions

There are many possible directions for future neuroscientific research concerning social pain. One avenue that will provide fruitful exploration concerns how the brain regulates the immune system in response to physical and social threats. The current literature supports the idea that the neural mechanisms for social and physical pain overlap, but how far does this overlap extend and what implications does this overlap have for people in terms of health and disease? A recent study from Slavich and colleagues (2010) provides initial evidence that individual differences in neural responses to social threat may make one more or less susceptible to disease. In their study, participants performed the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), in which they prepared and delivered an unrehearsed speech and performed mental arithmetic in front of a panel of socially rejecting raters. Participants then provided a saliva sample, which was assayed for two markers of inflammatory response: 1. a soluble receptor for tumor necrosis factor-α (sTNFαRII) and 2. interleukin-6 (IL-6). At a second laboratory session, a subsample of these participants played the Cyberball game, in which they experienced exclusion, during an fMRI scanning session. The authors found that the TSST increased levels of sTNFαRII and IL-6, compared to baseline levels. Once more, in region of interest analyses, increased activity within the dACC and anterior insula during exclusion (vs. inclusion) was associated with increased levels of sTNFαRII after the TSST, but not IL-6. These findings give initial evidence that the neural mechanisms underlying social pain are associated with susceptibility to inflammatory responses in socially stressful situations, which has implications for the link between stress and disease.

Another future direction for fruitful research centers around the emerging area of genomic imaging, in which investigators are able to model the neural responses towards a stimulus

among individuals genetically predisposed for various characteristics or not. For example, Way and colleagues (2009) conducted initial research that applied this method to the study of social rejection. They were interested in whether variation in the μ-opioid receptor gene (a site where morphine acts) was associated with individual differences in sensitivity to social rejection. In their study, participants completed a rejection sensitivity questionnaire and provided a saliva sample that was assayed for the A118G polymorphism (a measure of the μ-opioid receptor gene). A subsample of participants then completed the Cyberball game, in which they experienced exclusion, during a second laboratory session. The investigators expected that participants with the G allele on the A118G polymorphism would be more sensitive to rejection, because the G allele is related to the reduced potency of opiates. As expected, participants who were G allele carriers reported more sensitivity to rejection. Additionally, in region of interest analyses, activity in the dACC and anterior insula during exclusion (vs. inclusion) was greater for G allele carriers than A allele homozygotes. Moreover, activity in the dACC during exclusion (vs. inclusion) significantly mediated the association between individual variation in the A118G polymorphism and individual differences in rejection sensitivity. These findings provide initial evidence for the genetic overlap between physical and social pain, however much more work still needs to be done in this area.

11. Conclusion

Humans are social creatures, and the need to belong is a powerful motivator for sustenance of social integration. Over the past decade, social psychologists have worked hard to understand the consequences of rejection at the cognitive, emotional, and behavioral levels. However, we are just beginning to understand the neural basis underlying social rejection. Recently, social psychologists have been able to apply functional magnetic resonance imaging to this research area. Doing so, we have gained a better understanding of the neural similarities between physical and social pain. Specifically, psychologists have identified the dorsal anterior cingulate cortex and the anterior insula (areas associated with the affective component of physical pain) as particularly important in the processing of social rejection. More recently, researchers have employed fMRI procedures to extend upon this work. Through neuroimaging, psychologists have shown that an over-the-counter medication, acetaminophen, reduces feelings of rejection by dampening activity in the dACC and anterior insula during rejection experiences. Neuroimaging has also been useful in helping researchers identify those individuals who are most vulnerable to social rejection, exclusion, and ostracism.

As technology becomes more advanced and user-friendly, the researcher's toolkit will expand to incorporate new scientific approaches. Functional brain imaging can be applied in a variety of ways to the study of human behavior. This chapter is just one example of an area in which neuroimaging procedures can be easily adapted. Although we don't fully understand the neural basis of social pain, psychologists have been able to gain ground in this area because of the availability of fMRI technology.

The brain is an immensely complex organ. In order to gain a better understanding of the behaviors that it produces, we need to make full use of the research tools at our disposal.

Functional brain imaging can offer valuable insights to the social sciences. These insights lead to better questions, the generation of novel hypotheses, and more elegant methods for testing those hypotheses.

Author details

Richard S. Pond, Jr., Stephanie B. Richman, David S. Chester and C. Nathan DeWall

University of Kentucky, United States of America

References

[1] Abell, J.E., Hootman, J.M., Zack, M.M., Moriarty, D., Helmick, C.G. (2005). Physical activityand health related quality of life among people with arthritis. *Journal of Epidemiology and Community Health*, Vol. 59, No.5, (May 2005), pp. 380–385, ISSN 1470-2738.

[2] Apkarian, A.V., Bushnell, M.C., Treede, R., & Zubieta, J. (2005). Human brain mechanisms of pain perception and regulation in health and disease. *European Journal of Pain*, Vol.9, No.4, (August 2005), pp. 463–484, ISSN 1090-3801.

[3] Axelrod, R., & Hamilton, W.D. (1981). The evolution of cooperation. *Science.* Vol. 211,No.4489, (March 1981), pp. 1390-1396, ISSN 0036-8075.

[4] Aziz, Q., Schnitzler, A., & Enck, P. (2000). Functional neuroimaging of visceral sensations. *Journal of Clinical Neurophysiology*, Vol.17, No.6, (November 2000), pp. 604-612, ISSN 0736-0258.

[5] Barash. D.P. (1977). *Sociobiology and behavior,* Elsevier, ISBN 0444990364, New York.

[6] Barnard, G.W., Vera, H., Vera, M.I., & Newman, G. (1982). Til death do us part: A study of spouse murder. *Bulletin of the American Academy of Psychiatry and the Law,* Vol. 10, No.4, (December 1982), pp. 271-280, ISSN 7165803.

[7] Barrett, L.F., Tugade, M.M., & Engle, R.W. (2004). Individual differences in working memory capacity and dual-process theories of the mind. *Psychological Bulletin*, Vol. 130, No.4, (July 2004), pp.553-573, ISSN 00332909.

[8] Baumeister, R.F. (1990). Suicide as escape from the self. Psychological Review, Vol. 97, No.1,(January 1990), pp. 90-113, ISSN 1939-1471.

[9] Baumeister, R.F., & Leary, M.R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, Vol.117, No. 3, (May 1995), pp. 497-529, ISSN 0033-2909.

[10] Baumeister, R.F., Twenge, J.M., & Nuss, C.K. (2002). Effects of social exclusion on cognitive processes: Anticipated aloneness reduces intelligent thought. *Journal of Personality and Social Psychology*, Vol.83, No.4, (October 2002), pp. 817-827, ISSN 1939-1315.

[11] Baumeister, R.F., DeWall, C.N., Ciarocco, N.J., & Twenge, J.M. (2005). Social exclusion impairs self-regulation. *Journal of Personality and Social Psychology*, Vol.88, No.4 (April 2005), pp. 589-604, ISSN 1939-1315.

[12] Berkman, L.F., & Syme, S.L. (1979). Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda county residents. *American Journal of Epidemiology*, Vol.109, No.2, (February 1979), pp. 186-204, ISSN 0002-9262.

[13] Bolling, D.Z., Pitskel, N.B., Deen, B., Crowley, M.J., McPartland, J.C., Mayes, L.C., & Pelphrey, K.A. (2011). Dissociable brain mechanisms for processing social exclusion and rule violation. *Neuroimage*, Vol.54, No.3, (February 2011), pp. 2462-2471, ISSN 1095-9572.

[14] Brown, G., & Nicassio, P. (1987). Development of a questionnaire for the assessment of active and passive coping strategies in chronic pain patients. *Pain*. Vol.31, No.1, (October 1987), pp. 53–64, ISSN 0304-3959.

[15] Brown, J.L., Sheffield, D., Leary, M.R., & Robinson, M.E. (2003). Social support and experimental pain. *Psychosomatic Medicine*, Vol.65, No.2, (March-April 2003), pp.276–283, ISSN 1534-7796.

[16] Buckley, K., Winkel, R., & Leary, M.R. (2004). Reactions to acceptance and rejection: Effects of level and sequence of relational evaluation. *Journal of Experimental Social Psychology*, Vol.40, No.1, (January 2004), pp.14-28, ISSN 0022-1031.

[17] Burckardt, C.S. (2002). Nonpharmacologic management strategies in fibromyalgia. *Rheumatic Disease Clinics of North America*, Vol.28, No.2, (May 2002), pp. 291–304, ISSN 0889-857X.

[18] Burklund, L.J., Eisenberger, N.I., & Lieberman, M.D. (2007). The face of rejection: Rejection sensitivity moderates dorsal anterior cingulated activity to disapproving facial expressions. *Social Neuroscience*, Vol.2, No.3–4, (July 2007), pp. 238–253, ISSN 1747-0919.

[19] Bush, G., Luu, P., & Posner, M.I. (2000). Cognitive and emotional influences in anterior cingulated cortex. *Trends in Cognitive Sciences*, Vol.4, No.6, (June 2000), pp. 215–222, ISSN 1879-307X.

[20] Buss, D.M. (1990). The evolution of anxiety and social exclusion. *Journal of Social and Clinical Psychology*, Vol.9, No.2, (June 1990), pp. 196-210, ISSN 0736-7236.

[21] Buss, D.M. (1991). Evolutionary personality psychology. *Annual Review of Psychology*, Vol. 42, pp. 459-491, ISSN 0-8243-0242-7.

[22] Callahan, C.D. (2000). Stress, coping, and personality hardiness in patients with temporomandibular disorders. *Rehabilitative Psychology*, Vol.45, No.1, (February 2000), pp. 38–48, ISSN 1939-1544.

[23] Carden, S.E., & Hofer, M.A. (1990). Socially mediated reduction of isolation distress in rat pups is blocked by naltrexone but not by Ro 15–1788. *Behavioral Neuroscience*, Vol. 104, No.3, (June 1990), pp. 457–463, ISSN 1939-0084.

[24] Carden, S.E., Hernandez, N., & Hofer, M.A. (1996). The isolation and companion comfort responses of 7- and 3-day-old rat pups are modulated by drugs active at the opioid receptor. *Behavioral Neuroscience*, Vol.110, No.2, (April 1996), pp. 324–330, ISSN 1939-0084.

[25] Carlson, C.R., Bertrand, P.M., Ehrlich, A.D., Maxwell, A.W., & Burton, R.G. (2001). Physical self-regulation training for the management of temporomandibular disorders. *Journal of Orofacial Pain*, Vol.15, No.1, (Winter 2001), pp. 47–55, ISSN 11889647.

[26] Carter, C.S., MacDonald, III, A.M., Botvinick, M.M., Ross, L.L., Stenger, V.A., Noll, D., & Cohen, J. (2000). Parsing executive processes: Strategic vs. evaluative functions of the anterior cingulate cortex. *Proceedings of the National Academy of Sciences*, Vol.97, No.4, (February 2000), pp. 1944 – 1948, ISSN 0027-8424.

[27] Chalmers, B., Wolman, W.L., Nikodem, V.C., Gulmezoglu, A.M., & Hofmeyer, G.J. (1995). Companionship in labour: Do the personality characteristics of labour supporters influence their effectiveness? *Curationis*, Vol.18, No.4, (December 1995), pp. 77–80, ISSN 8697543.

[28] Cogan, R., & Spinnato, J.A. (1988). Social support during premature labor: Effects on labor and the newborn. *Journal of Psychosomatic Obstetrics and Gynecology*, Vol.8, No.3, (June 1988), pp. 209–216, 1743-8942.

[29] Craig, A.D., & Dostrovsky, J.O. (1999). Medulla to thalamus. In: *Textbook of pain*, P. Wall & R. Melzack (Eds.), pp. 183–214, Churchill Livingstone, ISBN 0443062528, New York.

[30] Crawford, M., & Gartner, R. (1992). *Women killing: Intimate femicide in Ontario, 1974-1990*. Women We Honour Action Committee, Toronto.

[31] DeWall, C.N., & Baumeister, R.F. (2006). Alone but feeling no pain: Effects of social exclusion on physical pain tolerance and pain threshold, affective forecasting, and interpersonal empathy. *Journal of Personality and Social Psychology*, Vol.91, No.1, (July 2006), pp. 1-15, ISSN 1939-1315.

[32] DeWall, C.N., MacDonald, G., Webster, G.D., Masten, C.L., Baumeister, R.F., Powell, C., Combs, D., Schurtz, D.R., Stillman, T.F., Tice, D.M., & Eisenberger, N.I. (2010). Acetaminophen reduces social pain: Behavioral and neural evidence. *Psychological Science*, Vol.21, No.7, (June 2010), pp. 931-937, ISSN 1467-9280.

[33] DeWall, C.N., Masten, C.L., Kashdan, T.B., Pond, Jr., R.S., Powell, C., Combs, D., & Schurtz, D.R. (2011). *Who is Most Vulnerable to Social Rejection? The Toxic Combination*

of Low Self-Esteem and Lack of Emotional Differentiation on Neural Responses to Rejection.
Unpublished manuscript, University of Kentucky.

[34] DeWall, C.N., Masten, C.L., Powell, C., Combs, D., Schurtz, D.R., & Eisenberger, N.I. (2011). Does the pain of rejection depend on attachment style? An fMRI study. *Social Cognitive & Affective Neuroscience,* Advance Access, (April 2011), ISSN 1749-5016.

[35] DeWall, C.N. & Richman, S.B. (2011). Social exclusion and the desire to reconnect. *Social and Personality Psychology Compass*, Vol.5, No.11, (November 2011), pp. 919-932, ISSN1751-9004.

[36] DeWall, C.N., Twenge, J.M., Gitter, S.A., & Baumeister, R.F. (2009). It's the thought that counts: The role of hostile cognition in shaping aggressive responses to social exclusion. *Journal of Personality and Social Psychology,* Vol.96, No.1, (January 2009), pp. 45-59, ISSN 1939-1315.

[37] DeWall, C.N., Twenge, J.M., Bushman, B.J., Im, C., & Williams, K.D. (2010). Acceptance by one differs from acceptance by none: Applying social impact theory to the rejection-aggression link. *Social Psychological and Personality Science*, Vol.1, No.2, (April 2010), pp. 168-174, ISSN 1948-5506.

[38] Downey, G., Freitas, A.L., Michaelis, B., & Khouri, H. (1998). The self-fulfilling prophecy in close relationships: Rejection sensitivity and rejection by romantic partners. *Journal of Personality and Social Psychology,* Vol.75, No.2, (August 1998), pp. 545-560, 1939-1315.

[39] Eisenberger, N.I., & Lieberman, M.D. (2004). Why rejection hurts: A common neural alarm system for physical and social pain. *Trends in Cognitive Sciences*, Vol.8, No.7, (July 2004), pp.294-300, ISSN 1364-6613.

[40] Eisenberger, N.I., Lieberman, M.D., & Williams, K.D. (2003). Does rejection hurt? An fMRI study of social exclusion. *Science*, Vol.302, No.5643, (October 2003), pp. 290-292, ISSN 1095-9203.

[41] Eisenberger, N.I., Taylor, S.E., Gable, S.L., Hilmert, C.J., & Lieberman, M.D. (2007). Neural pathways link social support to attenuated neuroendocrine stress responses. *Neuroimage*, Vol.35, No.4, (May 2007), pp. 1601-1612, ISSN 1053-8119.

[42] Epker, J., & Gatchel, R.J. (2000). Coping profile differences in the biopsychosocial functioning of patients with temporomandibular disorder. *Psychosomatic Medicine,* Vol.62, No.1, (January 2000), pp. 69–75, ISSN 1534-7796.

[43] Feeney, J.A., Noller, P., & Hanrahan, M. (1994). Assessing adult attachment. In: *Attachment in adults: Clinical and developmental perspectives*, M.B. Sperling, and W.H. Berman (Eds.), pp. (128–152). Guilford Press, ISBN 0898625475, New York.

[44] Felmingham, K., Kemp, A., Williams, L., Das, P., Hughes, G., Peduto, A., and Bryant, R. (2007). Changes in anterior cingulate and amygdala after cognitive behavior thera-

py of posttraumatic stress disorder. *Psychological Science,* Vol.18, No.2, (February 2007), pp. 127–129, ISSN 1467-9280.

[45] Ferrando, M., Andreu, Y., Galdon, M.J., Dura, E., Poveda, R., & Bagan, J.V. (2004) Psychological variables and temporomandibular disorders: Distress, coping, and personality. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics,* Vol.98, No.2, (August 2004), pp. 153–160, ISSN 1531-6541.

[46] Foltz, E.L., & White, L.E. (1968). The role of rostral cingulotomy in "pain" relief. *International Journal of Neurology,* Vol.6, pp. 353–373, ISSN 0020-7446.

[47] Fraley, R.C., & Shaver, P.R. (2000). Adult romantic attachment: theoretical developments, emerging controversies, and unanswered questions. *Review of General Psychology,* Vol.4, No.2, (June 2000), pp.132–154, ISSN 1089-2680.

[48] Gaertner, L., JIuzzini, J., & O'Mara, E.M. (2008). When rejection by one fosters aggression against many: Multiple-victim aggression as a consequence of social rejection and perceived groupness. *Journal of Experimental Social Psychology,* Vol.44, No.4 (July, 2008), pp. 958-970, ISSN 0022-1031.

[49] Gardner, W.L., Pickett, C.L., & Brewer. M.B. (2000). Social exclusion and selective memory: How the need to belong influences memory for social events. *Personality and Social Psychology Bulletin,* Vol.26, No.4, (April 2000), pp. 486–496, ISSN 1552-7433.

[50] Harmon-Jones, E., & Winkielman, P. (Eds.). (2007). *Social Neuroscience: Integrating Biological and Psychological Explanations of Social Behavior,* Guilford Publications, ISBN 978-159-3854-04-1, New York, NY.

[51] Harris, M.J. (2009). *Bullying, Rejection, and Peer Victimization: A Social Cognitive Neuroscience Perspective.* Springer Publishing Company, ISBN 978-082-6103-78-9, New York, NY.

[52] Herman, B.H., & Panksepp, J. (1978). Effects of morphine and naloxone on separation distress and approach attachment: Evidence for opiate mediation of social affect. *Pharmacology, Biochemistry, & Behavior,* Vol.9, No.2, (August 1978), pp. 213–220, 0091-3057.

[53] Hogan, R., Jones, W.H., & Cheek, J.M. (1985). Socioanalytic theory: An alternative to armadillo psychology. In: *The self and social life,* B.R. Schlenker (Ed.), pp. (175-198). McGraw-Hill, ISBN 0070553076, New York.

[54] House, J.S., Landis, K.R., & Umberson, D. (1988). Social relationships and health. *Science,* Vol.241, No.4865, (July 1988), pp. 540-545, ISSN 0036-8075.

[55] Insel, T.R., & Winslow, J.T. (1991). Central administration of oxytocin modulates the infant rat's response to social isolation. *European Journal of Pharmacology,* Vol.203, No. 1, (October 1991), pp. 149–152, ISSN 1665788.

[56] Izuma, K., Saito, D.N., & Sadato, N. (2008). Processing of social and monetary rewards in the human striatum. *Neuron*, Vol.58, No.2, (April 2008), pp. 284-294, ISSN 0896-6273.

[57] Janda, L.H., Fulk, J., Janda, M., & Wallace, J. (1995). *The development of a test of General Mental Abilities.* Unpublished manuscript, Old Dominion University.

[58] Janda, L. (1996). *The psychologists' book of self-tests.* Berkley, ISBN 0399522115, New York.

[59] Kashdan, T.B., Ferssizidis, P., Collins, R.L., & Muraven, M. (2010). Emotion differentiation as resilience against excessive alcohol use: An ecological momentary assessment in underage social drinkers. *Psychological Science*, Vol.21, No.9, (September 2010), pp.1341-1347, ISSN 1467-9280.

[60] Keefe, F.J., Brown, G.K., Wallston, K.A., Caldwell, D.S. (1989). Coping with rheumatoid arthritis pain: Catastrophizing as a maladaptive strategy. *Pain*, Vol.37, No.1, (April 1989), pp. 51–56, ISSN 0304-3959.

[61] Kehoe, P., & Blass, E. M. (1986). Opioid-mediation of separation distress in 10-day-old rats: Reversal of stress with maternal stimuli. *Developmental Psychobiology*, Vol.19, No.4, (July 1986), pp. 385–398, ISSN 1098-2302.

[62] Kirschbaum, C., Pirke, K.M., & Hellhammer, D.H. (1993). The 'Trier Social Stress Test'—a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*, Vol.28, No.1–2, (June 1993), pp. 76–81, ISSN 0302-282X.

[63] Klaus, M., Kennel, J., Robertson, S., & Rosa, R. (1986). Effects of social support during parturition on maternal and infant mortality. *British Medical Journal*, Vol.293, No. 6547, (September 1986), pp. 585–597, ISSN 0267-0623.

[64] Konecka, A.M., & Sroczynska, I. (1990). Stressors and pain sensitivity in CFW mice: Role of opioid peptides. *Archives Internationales de Physiologie et de Biochimie*, Vol.98, No.5, pp. 245–252, ISSN 0003-9799.

[65] Kong, J., Gollub, R. L., Rosman, I. S., Webb, J. M., Vangel, M. G., Kirsch, I., and Kaptchuk, T.J. (2006). Brain activity associated with expectancy-enhanced placebo analgesia as measured by functional magnetic resonance imaging. *The Journal of Neuroscience*, Vol.26, No.2, (January 2006), pp. 381–388, ISSN 0270-6474.

[66] Kross, E., Berman, M.G., Mischel, W., Smith, E.E., & Wager, T.D. (2011). Social rejection shares somatosensory representations with physical pain. *Proceedings of the* National Academy of Sciences, Vol.108, No.15, (April 2011), pp. 6270-6275, ISSN 1091-6490.

[67] Kross, E., Egner, T., Ochsner, K., Hirsch, J., & Downey, G. (2007). Neural dynamics of rejection sensitivity. *Journal of Cognitive Neuroscience*, Vol.19, No.6, (June 2007), pp. 945–956, ISSN 1530-8898.

[68] Landro, N.I., Stiles, T.C., & Sletvold, H. (1997). Memory functioning in patients with primary fibromyalgia and major depression and healthy controls. *Journal of Psychosomatic Research,* Vol.42, No.3, (March 1997), pp. 297-306, ISSN 0022-3999.

[69] Lane, R.D., Reiman, E.M., Ahern, G.L., Schwartz, G.E., & Davidson, R.J. (1997). Neuroanatomical correlates of happiness, sadness, and disgust. *American Journal of Psychiatry*, Vol.154, No.7, (July 1997), pp. 926-933, ISSN 0002-953X.

[70] Leary, M.R. & Springer, C.A. (2001). Hurt feelings: The neglected emotion. In: *Aversive behaviors and interpersonal transgression,* R. Kowalski (Ed.), pp. (151-175). American Psychological Association, ISBN 1-55798-716-5, Washington DC.

[71] Leary, M.R., Kowalski, R.M., Smith, L., & Phillips, S. (2003). Teasing, rejection, and violence: Case studies of the school shootings. *Aggressive Behavior,* Vol.29, No.3, (June 2003), pp. 202-214, ISSN 1098-2337.

[72] Leary, M.R., Tambor, E.S., Terdal, S.J., & Downs, D.L. (1995). Self-esteem as an interpersonal monitor: The sociometer hypothesis. *Journal of Personality and Social Psychology,* Vol.68, No.3, (March 1995), pp.518-530, ISSN 0022-3514.

[73] Leary, M.R., Twenge, J.M., & Quinlivan, E. (2006). Interpersonal Rejection as a Determinant of Anger. *Personality and Social Psychology Review,* Vol.10, No.2, (May, 2006), pp. 111-132, ISSN 1532-7957.

[74] Lidderdale, J.M., & Walsh, J.J. (1998). The effects of social support on cardiovascular reactivity and perinatal outcome. *Psychology and Health*, Vol.13, No.6, (May 1998), pp. 1061–1070, ISSN 1476-8321.

[75] Lieberman, M.D. (2007). Social cognitive neuroscience, In: *Encyclopedia of Social Psychology Vol. 2*, Baumeister, R.F., & Vohs, K.D. (Eds.), pp. 885-887, Sage Press, ISBN 978-141-2916-70-7, Thousand Oaks, CA.

[76] Lieberman, M.D. (2010). Social cognitive neuroscience, In: *Handbook of Social Psychology 5th ed.*, Fiske, S.T., Gilbert, D.T., & Lindzey, G. (Eds.), pp. 143-193, McGraw-Hill, ISBN 047-013-7479, New York, NY.

[77] Lieberman, M.D., Eisenberger, N.I., Crockett, M.J., Tom, S.M., Pfeifer, J.H., & Way, B.M. (2007). Putting feelings into words: Affect labeling disrupts amygdala activity in response to affective stimuli. *Psychological Science,* Vol.18, No.5, (May 2007), pp. 421–428, ISSN 0956-7976.

[78] MacDonald, G., & Leary, M.R. (2005). Why does social exclusion hurt? The relationship between social and physical pain. *Psychological Bulletin,* Vol.131, No.2, (March 2005), pp. 202–223, ISSN 1939-1455.

[79] MacLean, P.D., & Newman, J.D. (1988). Role of midline frontolimbic cortex in production of the isolation call of squirrel monkeys. *Brain Research*, Vol.450, No.1-2, (May 1988), pp. 111-123, ISSN 0006-8993.

[80] Maner, J.K., DeWall, C.N., Baumeister, R.F., & Schaller, M. (2007). Does social exclusion motivate withdrawal or reconnection? Resolving the "porcupine problem." *Journal of Personality and Social Psychology*, Vol.92, No.1, (January 2007), pp. 42-55, ISSN 1939-1315.

[81] Masten, C.L., Telzer, E.H., & Eisenberger, N.I. (2011). An fMRI investigation of attributing negative social treatment to racial discrimination. *Journal of Cognitive Neuroscience*, Vol.23, No.5, (May 2011), pp. 1042-1051, ISSN 1530-8898.

[82] Melzack, R. & Casey, K. (1968). Sensory, motivational and central control determinants of pain: A new conceptual model. In: *The Skin Senses,* D. Kenshado (Ed.), (pp. 423-439). C. C. Thomas, ISBN BWB5857742, Springfield, IL.

[83] Mitchell, J.P., Cloutier, J., Banaji, M.R., & Macrae, C.N. (2006). Medial prefrontal dissociations during processing of trait diagnostic and nondiagnostic person information. *Social Cognitive and Affective Neuroscience*, Vol.1, No.1, (May 2006), pp. 49-55, ISSN 0006-8993.

[84] Moll, J., de Oliveira-Souza, R., Eslinger, P.J., Bramati, I.E., Mourão-Miranda, J., Andreiuolo, P.A., & Pessoa, L. (2002). The neural correlates of moral sensitivity: A functional magnetic resonance imaging investigation of basic and moral emotions. *The Journal of Neuroscience*, Vol.22, No.7, (April 2002), pp. 2730 -2736, ISSN 1529-2401.

[85] Moreland, R.L. (1987). The formation of small groups. In: *Group processes: Review of personality and social psychology Vol 8,* C. Hendrick (Ed.), pp. (80-110). Sage, ISBN 0803930720, Newbury Park, CA.

[86] Murphy, M.R., MacLean, P.D., & Hamilton, S.C. (1981). Species-typical behavior of hamsters deprived from birth of the neocortex. *Science*, Vol.213, No.4506, (July 1981), pp.459–461, ISSN 0036-8075.

[87] Naranjo, J.R., & Fuentes, J.A. (1985). Association between hypoalgesia and hypertension in rats after short-term isolation. *Neuropharmacology*, Vol.24, No.2, (February 1985), pp. 167–171, ISSN 0028-3908.

[88] Nichols, D.S., Glenn, T.M. (1994). Effect of aerobic exercise on pain perception, affect, and level of disability in individuals with fibromyalgia. *Physical Therapy*, Vol.74, No. 4, (April 1994), pp. 327–332, ISSN 8140145.

[89] Niven, C. (1985). How helpful is the presence of the husband at childbirth? *Journal of Reproductive and Infant Psychology*, Vol.3, No.2, pp. 45–53, ISSN 1469-672X.

[90] Onoda, K., Okamoto, Y., Nakashim, K., Nittono, H., Yoshimura, S., Yamawaki, S., Yamaguchi, S., & Ura M. (2010). Does low self-esteem enhance social pain? The relationship between trait self-esteem and anterior cingulate cortex activation induced by ostracism. *Social Cognitive and Affective Neuroscience,* Vol.5, No.4, (December 2010), pp.385-391, ISSN 1749-5016.

[91] Panksepp, J. (1998). *Affective neuroscience: The foundations of human and animal emotions*. Oxford University Press, ISBN 0-19-509673-8, London.

[92] Panksepp, J., Herman, B.H., Conner, R., Bishop, P., & Scott, J.P. (1978). The biology of social attachments: Opiates alleviate separation distress. *Biological Psychiatry*, Vol.13, No.5, (October 1978), pp. 607–618, ISSN 0006-3223.

[93] Panksepp, J., Vilberg, T., Bean, N.J., Coy, D.H., & Kastin, A.J. (1978). Reduction of distress vocalization in chicks by opiate-like peptides. *Brain Research Bulletin*, Vol.3, No.6,(November 1978), pp. 663-667, ISSN 0361-9230.

[94] Park, D.C., Glass, J.M., Minear, M., & Crofford, L.J. (2001). Cognitive function in fibromyalgia patients. *Arthritis and Rheumatism*, Vol.44, No.9, (September 2001), pp. 2125-2133, ISSN 0004-3591.

[95] Petrovic, P., Dietrich, T., Fransson, P., Andersson, J., Carlsson, K., & Igvar, M. (2005). Placebo in emotion processing—induced expectations of anxiety relief activate a generalized modulatory network. *Neuron*, Vol.46, No.6, (June 2005), pp. 957–969, ISSN 0896-6273.

[96] Petrovic, P., & Ingvar, M. (2002). Imaging cognitive modulation of pain processing. *Pain*, Vol.95, No.1-2, (January 2002), pp. 1-5, ISSN 0304-3959.

[97] Phillips, J.M., & Gatchel, R.J. (2000). Extraversion–introversion and chronic pain: Locus of control in the patient with chronic pain. In: *Personality characteristics of patients with pain*, R. Gatchel & J. Weisberg (Eds.), pp. (181–202). American Psychological Association, ISBN 1-55798-646-0, Washington, DC.

[98] Price, D.D. (2000). Psychological and neural mechanisms of the affective dimension of pain. *Science*, Vol.288, No.5472, (June 2000), pp. 1769–1772, ISSN 0036-8075.

[99] Rainville, P., Duncan, G.H., Price, D.D., Carrier, B., & Bushnell, M.C. (1997). Pain affect encoded in human anterior cingulated but not somatosensory cortex. *Science*, Vol.277, No.5328, (August 1997), pp. 968–971, ISSN 0036-8075.

[100] Rushen, J., Boissy, A., Terlouw, E.M., & de Passille, A.M. (1999). Opioid peptides and behavioral and physiological responses of dairy cows to social isolation in unfamiliar surroundings. *Journal of Animal Science*, Vol.77, No.11, (November 1999), pp. 2918-2924, ISSN 1525-3163.

[101] Sebastian, C.L., Roiser, J.P., Tan, G.C., Viding, E., Wood, N.W., & Blakemore, S.J. (2010). Effects of age and MAOA genotype on the neural processing of social rejection. *Genes, Brain & Behavior*, Vol.9, No.6, (June 2010), pp. 628-637, ISSN 1601-183X.

[102] Sharp, T.J., & Harvey, A.G. (2001). Chronic pain and post-traumatic stress disorder: Mutual maintenance? *Clinical Psychology Review*, Vol.21, No.6, (August 2001), pp. 857–877, ISSN 0272-7358.

[103] Simmons, A., Matthews, S.C., Feinstein, J.S., Hitchcock, C., Paulus, M.P., & Stein, M.B. (2008). Anxiety vulnerability is associated with altered anterior cingulate re-

sponse to an affective appraisal task. *NeuroReport*, Vol.19, No.10, (July 2008), pp. 1033–1037, ISSN 0959-4965.

[104] Slavich, G.M., Way, B.M., Eisenberger, N.I., & Taylor, S.E. Neural sensitivity to social rejection is associated with inflammatory responses to social stress. *Proceedings of the National Academy of Sciences*, Vol.107, No.33, (August 2010), pp. 14817-14822, ISSN 0027-8424.

[105] Smith, A.K., White, P.D., Aslakson, E., Vollmer-Conna, U., & Rajeevan, M.S. (2006). Polymorphisms in genes regulating the HPA axis associated with empirically de-lineated classes of unexplained chronic fatigue. *Pharmacogenomics*, Vol.7, No.3, (April 2006), pp 387–394, ISSN 16610949.

[106] Snow-Turek, A.L., Norris, M.P., Tan, G. (1996) Active and passive coping strategies in chronic pain patients. *Pain*, Vol.64, No.3, (March 1996). pp. 455–462, ISSN 0304-3959.

[107] Solberg Nes, L., Roach, A.R., & Sergerstrom, S.C. (2009). Executive functions, self-regulation, and chronic pain: a review. *Annals of Behavioral Medicine*, Vol.37, No.2, (April 2009), pp. 173-183, ISSN 0883-6612, 1532-4796.

[108] Somerville, L.H., Kelley, W.M., & Heatherton, T.F. (2010). Self-esteem modulates me-dial prefrontal cortical responses to evaluative social feedback. *Cerebral Cortex*, Vol. 20, No.12, (December 2010), pp.3005-3013, ISSN 1047-3211.

[109] Spear, L.P., Enters, E.K., Aswad, M.A., & Louzan, M. (1985). Drug and environmen-tally induced manipulations of the opiate and serotonergic systems alter nociception in neonatal rat pups. *Behavioral and Neural Biology*, Vol.44, No.1, (July 1985), pp. 1–22, ISSN 0163-1047.

[110] Sufka, K.J., & Hughes, R.A. (1990). Dose and temporal parameters of morphine-in-duced hyperalgesia in domestic fowl. *Physiology & Behavior*, Vol.47, No.2, (February 1990), pp. 385–387, ISSN 0031-9384.

[111] Sufka, K.J., & Weed, N.C. (1994). Construct validation of behavioral indices of isola-tion stress and inflammatory nociception in young domestic fowl. *Physiology & Be-havior*, Vol.55, No4., (April 1994), pp. 741–746, ISSN 0031-9384.

[112] Tugade, M.M., Fredrickson, B.L., & Barrett, L.F. (2004). Psychological resilience and emotional granularity: Examining the benefits of positive emotions on coping and health. *Journal of Personality*, Vol.72, No.6, (December 2004), pp.1161-1190, ISSN 1467-6494.

[113] Twenge, J.M., Baumeister, R.F., Tice, D.M., & Stucke, T.S. (2001). If you can't join them, beat them: Effects of social exclusion on aggressive behavior. *Personality and Social Psychology*, Vol.81, No.6, (December, 2001), pp.1058-1069, ISSN 1939-1315.

[114] Twenge, J.W., Cantanese, K.R., & Baumeister, R.F. (2002). Social exclusion causes self-defeating behavior. *Journal of Personality and Social Psychology*, Vol.83, No.3, (September, 2002), pp. 606-615, ISSN 1939-1315.

[115] Twenge, J.M., Catanese, K.R., & Baumeister, R.F. (2003). Social exclusion and the deconstructed state: Time perception, meaninglessness, lethargy, lack of emotion, and self-awareness. *Journal of Personality and Social Psychology*, Vol.85, No.3, (September 2003), pp. 409–423, ISSN 1939-1315.

[116] Way, B.M., Taylor, S.E., & Eisenberger, N.I. (2009). Variation in the mu-opioid receptor gene (OPRM1) is associated with dispositional and neural sensitivity to social rejection.*Proceedings of the National Academy of Sciences*, Vol.106, No.35, (September 2011), pp. 15079-15084, 0027-8424.

[117] Wiedenmayer, C.P., Goodwin, G.A., & Barr, G.A. (2000). The effect of periaqueductal gray lesions on responses to age-specific threats in infant rats. *Developmental Brain Research*, Vol.120, No.2, (April 2000), pp. 191–198, ISSN 0165-3806.

[118] Williams, K.D., Cheung, C.K.T., & Choi, W. (2000). CyberOstracism: Effects of being ignored over the Internet. *Journal of Personality and Social Psychology*, Vol.79, No.5, (November 2000), pp.748–762, ISSN 00223514.

[119] Zadro, L., Williams, K.D., & Richardson, R. (2004). How low can you go? Ostracism by a computer is sufficient to lower self-reported levels of belonging, control, self-esteem, and meaningful existence. *Journal of Experimental Social Psychology*, Vol.40, No. 4, (July 2004), pp. 560-567, ISSN 0022-1031.

[120] Zautra, A.J., Hamilton, N.A., & Burke, H.M. (1999). Comparison of stress responses in Women with two types of chronic pain: Fibromyalgia and osteoarthritis. *Cognitive Therapy and Research*, Vol.23, No.2, (April 1999), pp. 209–230, ISSN 1573-2819.