Chapter 2
The Distress-Relief Dynamic in Attachment Bonding

Lane Beckes and James A. Coan

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Human beings need other human beings for their general health and well-being (c.f., Baumeister and Leary 1995; Holt-Lunstad et al. 2010). Awareness of the importance of interpersonal bonds grew rapidly in the mid-twentieth century due to the work of psychological pioneers like John Bowlby (e.g., 1969/1982) and Harry Harlow (1958). Their work demonstrated that for infant monkeys and humans, physical touch, sensitive care, and a consistent primary relationship are fundamental to healthy development.

Bowlby's (e.g., 1969/1982) attachment theory continues to have a tremendous impact on the field of psychology. His theory predicted both normative and individual differences in the functioning of a putative attachment system. For many years the field focused largely on the individual differences in attachment first documented by Mary Ainsworth and her colleagues (Ainsworth et al. 1978). Despite this focus, as the branches of attachment theory have expanded into areas such as attachment in adults (c.f., Hazan and Shaver 1987; Mikulincer and Shaver 2007), renewed efforts to understand the normative processes that form attachment bonds are receiving attention. Further, insights concerning normative processes are beginning to shed light on the formation of attachment bonds and individual differences in them.

In this chapter we explore some of the normative processes that lead to social bonding and the development of attachment styles. First, we explore the distress-relief dynamic as a fundamental process in the formation of feelings of security in adults. Second, we tackle the issue of how and why attachment bonds form, how different styles emerge, and how the distress-relief dynamic contributes to these

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processes. Third, we discuss how our work and the work of other social affective neuroscientists influences the depth and breadth of our understanding of distress-relief processes.

In this review, we address several key issues regarding the development of attachment bonds and attachment security. The first issue is how security develops through a distress-relief dynamic in which interpersonal responsiveness plays a crucial role. The central argument of this chapter is that attachment security develops through repeated iterations of a sequence of distress followed by seeking proximity to another person. If that other is responsive to the distressed individual's state, a sense of relief or felt security arises (c.f., Mikulincer and Shaver 2003). This form of negative reinforcement conditioning, we argue, produces over time a secure attachment bond, which buffers an individual from the stressors of daily life. This is the process that we refer to as the distress-relief dynamic. Moreover, we argue that alterations in the variability of this negative reinforcement sequence can lead to insecure bonds. For example, inconsistent responsiveness may lead to extinction resistance and hyperactive support-seeking behavior.

We should emphasize at the outset that this is not the only process through which attachment bonds form. The normative formation of attachment quality is not the same as the normative formation of an attachment bond, although the two are intimately linked, and the formation of a secure bond necessarily implies the formation of an attachment bond. This leads to the second set of issues we address here, namely how attachment bonds form, and what processes lead to the development of different qualities of attachment. Here we argue that the distress-relief dynamic is critical in determining the type of bond, although other kinds of social contact may foster attachment bonds in addition to the distress-relief dynamic. Specifically, sex, play, caregiving, and general familiarity may all play a role in bond formation, but they may have little influence on the quality of that bond, secure or insecure. Throughout this chapter it is important to keep in mind that attachment quality and attachment bonds are not the same.

Threat and Responsiveness in the Development of Attachment Security

Feelings of attachment security provide a person with a number of advantages. Priming the availability of attachment figures elevates mood (e.g., Mikulincer et al. 2001b), diminishes trauma-related cognition (Mikulincer et al. 2006), and enhances helping behavior (Mikulincer et al. 2001a; Mikulincer et al. 2003a). Further, secure attachment in adulthood is associated with greater relationship satisfaction and more positive means of conflict resolution (e.g., Selcuk et al. 2010; Carnelley et al. 1994; Rholes et al. 2006). Despite this, the process by which secure bonds are formed in the initial stages of a relationship remains relatively unexplored.

Expanding on Bowlby (e.g., 1969/1982), Mikulincer and Shaver (2003; Mikulincer et al. 2003b) argue that attachment styles develop after repeated iterations of

a threat-response sequence. According to this perspective, the attachment system is activated by signs of threat, which motivate the seeking of proximity to an external or internalized attachment figure. If the attachment figure is available, attentive, and responsive, then the threatened individual experiences relief and stress reduction, which contributes to an overall sense of felt security (Sroufe and Waters 1977). Alternatively, if attachment figures are not available, attentive, or responsive, individuals will engage in alternative strategies to meet their attachment needs—strategies associated with attachment insecurity. A relatively stable style of attachment emerges as a function of repeated iterations of one of these processes, leading individuals to respond more frequently and automatically with whichever strategy has been most commonly used.

Threat and Social Affiliation

Abundant evidence for a connection between threat and the desire to affiliate exists in the psychological literature. Despite varied nuances and interpretations, the body of social psychological research points to one salient fact: Threats of all kinds increase affiliative motivation.

Social Psychological Evidence

Schachter (1959), for example, found that individuals were more likely to affiliate with similar others when under the threat of electric shock. He argued that this occurs because affiliation with similar others provides an opportunity for social comparison, allowing a person to determine the appropriateness of his or her emotional state. In apparent contradiction, others have found that anxious individuals, as opposed to fearful ones, are less likely to affiliate with similar others and more likely to affiliate with dissimilar others (Sarnoff and Zimbardo 1961; Firestone et al. 1973; see Shaver and Klinnert 1982, for a review). In the attraction literature, many studies have noted that people find potential mates more attractive after experiencing a negatively arousing event such as crossing a shaky bridge or exposure to electric shock or aversive noises (e.g., Allen et al. 1989; Brehm et al. 1978; Dutton and Aron 1974; Jacobs et al. 1971; Kenrick and Johnson 1979; Riordan and Tedeschi 1983). As with the social comparison literature, such studies have inspired several alternative explanations for the link between negative arousal and attraction (e.g., misattribution of arousal, response facilitation, and negative reinforcement). Each perspective has been challenged by others, yet the persistent fact that negative arousal often promotes affiliation remains.

Similarly, threatening and painful events can motivate increased group identification (e.g., Aronson and Mills 1959), even when the pain and threat find their source within the very group with which one identifies. Harsh treatment related to hazing during initiation to collegiate groups of various kinds is associated with

increased social identification and social dependence (Keating et al. 2005). Alternatively, external threats to groups, such as the 9/11 attacks in the USA, are known to increase group identification, bolstering nationalistic or patriotic identities (Li and Brewer 2004). Thus, threat-affiliation dynamics exist at multiple levels of social organization.

Attachment Evidence

In the adult attachment and social support literature, numerous studies have indicated a link between threat and affiliation. Greater stress and problem severity have been associated with increased support seeking in people who possess positive schemas of others (Lopez et al. 1998), more support seeking generally (Kobak and Duemmler 1994; Lazarus and Folkman 1984), and more direct support seeking in interactions between romantic partners (Collins and Feeney 2000). Experimentally presented acute stressors also induce support seeking in securely attached romantic couples (e.g., Simpson et al. 1992), and separations induce proximity seeking (e.g., Fraley and Shaver 1998). Moreover, experimentally induced threat primes increase the accessibility of social representations (Mikulincer et al. 2000), the accessibility of attachment figure's names (Mikulincer et al. 2002), and recall, by adults, of positive interactions with parents (Cox et al. 2008). Despite decades of interest in this subject, the precise mechanisms remain debatable. Recently, however, social neuroscientists have begun to provide some possible mechanisms that may shed light on higher-level social and psychological mechanisms.

Neurobiological Evidence

Recent theory and empirical findings are suggestive of the hypothesis that the neuropeptide oxytocin is released in response to threatening stimuli in order to prepare individuals to seek out and/or provide social support. Taylor's (2006; Taylor et al. 2000) "tend and befriend" model argues that people have increased affiliative motivations when under threat because of a link between environmental threats and oxytocin release that evolved because of the importance of finding allies and defending offspring. Supporting the "tend and befriend" hypothesis, oxytocin has been linked to affiliative motivation and behavior (Insel 1997) such as social grooming and maternal care in nonhuman animals (Panksepp et al. 1999). In humans, women who experience laboratory challenges have higher cortisol stress responses if they also have higher plasma oxytocin levels (Taylor et al. 2006), and elevated plasma oxytocin has been associated with relationship distress (Grewen et al. 2005; Turner et al. 1999). Similarly, indicators of trust, such as generosity in economic games, have been linked to experimentally administered oxytocin (e.g., Kosfeld et al. 2005; Zak et al. 2007), plasma oxytocin levels (Zak et al. 2005), and polymorphisms in the oxytocin receptor gene (Israel et al. 2009).

Oxytocin is likely involved in organizing perception and behavior in ways that increase social approach and inhibit social withdrawal (Kemp and Guastella 2011). It inhibits amygdala activity (implicated in avoidance motivation) in relation to negative social targets (Baumgartner et al. 2008; Domes et al. 2007a), increases the assessment of attractiveness and trustworthiness of target faces (Theodoridou et al. 2009), and improves performance on tasks that require accurate identification of emotional facial expressions (Domes et al. 2007b). Further, recent evidence suggests that methylation of the oxytocin receptor gene (methylation diminishes the expression of a gene) is associated with neural responses to animacy displays (e.g., Jack et al. 2012), indicating a role for oxytocin in social perception more broadly. Thus, one critical reason for the link between threat and affiliation may be evolved mechanisms involving oxytocin (and the highly similar peptide vasopressin; see Carter et al. 2008, for a review and a discussion of sex differences) that promote social approach during stressful experiences.

This explanation fits well with the seemingly disparate findings that oxytocin is, on the one hand, associated with relationship distress and, on the other hand, with trust, social approach, and attraction. If oxytocin motivates social approach, it may do so in both negative and positive contexts. For example, if one's primary romantic relationship is in distress, the adaptive response is usually to attempt to repair it. This requires social approach, which is enhanced by oxytocin. This motivation for social approach, however, may not always be positively valenced. Indeed, Kemp and Guastella (2011) argue that oxytocin should be associated with darker aspects of social approach as well, such as anger or aggression. From this perspective aggressive mate-guarding behavior, jealousy, and other negative social approach behaviors may be motivated partly by oxytocin.

Responsiveness and Felt Security

There is now considerable evidence for the second part of the distress-relief dynamic: the sense of safety that emerges from social contact with responsive others. The concept of responsiveness is operationalized differently depending on the methods and traditions of a particular subfield. In studies of communication, the relevance of verbal and nonverbal communication by a responder to a person's distress communication is highlighted (e.g., Davis 1982). In social psychological studies, the focus is often on whether each party perceives the other to be providing "validation" (Reis et al. 2004). In observational studies, responsiveness can be gauged by coders in terms of engagement and understanding (e.g., Allen et al. 2007; Coan et al. 2013). And from a behavioral perspective, nonverbal behaviors such as physical touch, physical warmth, eye contact, facial expressions, and licking and grooming are often used as indicators of responsiveness (e.g., Coan et al. 2006; Coan et al. 2013; Harlow 1958; Hofer 2006; Beckes et al. 2010; Champagne et al. 2003).

Social Psychological Evidence

Much of the social psychological work on responsiveness has been summarized by Reis et al. (2004), who focus on the construct *perceived partner responsiveness*. They argue that perceived responsiveness is the *core construct* in interpersonal relationships, which, while broad in scope, has tremendous organizing power. For example, mutual validation is associated with low levels of marital distress (Gottman 1979), interpersonal synchrony between mothers and infants is associated with infant security (Reddy et al. 1997), and perceived social support is a strong predictor of stress and health outcomes (e.g., Cohen 1991). Although this literature is complex (e.g., expectations have been found to interact with enacted support to determine whether a partner is responsive, with higher expectations being placed on close others; e.g., Clark and Mills 1993), the gist is clear: Perceived responsiveness matters to health, well-being, and relationship functioning.

Attachment and Social Support Evidence

The attachment literature has advanced some significant evidence for the link between responsiveness and felt security (see Sbarra and Hazan 2008). For example, the presence of a romantic partner has been associated with a diminished stress response in physiological measures (Feeney and Kirkpatrick 1996), and individuals who have responsive partners report a greater sense of being cared for and a more elevated mood after a supportive interaction (Collins and Feeney 2000). Further, thoughts of attachment figures reduce the accessibility of thoughts of death after a mortality salience manipulation (Cox et al. 2008) and facilitate recovery after thinking about an upsetting personal experience (Selcuk et al. 2012) indicating a reduction in negative rumination following access to representations of attachment figures. Similar inferences can be derived from the social support literature (see Uchino 2006, or Uchino et al. 1996, for a review). This literature contains evidence that social support reduces autonomic nervous system load and boosts immune function during stressful tasks and over time. For example, studies have found links between social support and lower blood pressure (e.g., Kamarck et al. 1990), decreased cortisol (e.g., Turner-Cobb et al. 2000), and improved immune functioning (e.g., Lutgendorf et al. 2005). Indeed, this extensive literature highlights the powerful effect that high quality social support has on individual health and longevity (see Holt-Lunstad et al. 2010, for a meta-analysis and review).

Neurobiological Evidence

In neuroscience, responsiveness has rarely been studied. Despite this lack, many basic behavioral measures, manipulations, and conceptualizations that are likely to be affected by perceived responsiveness have been studied. Beginning with Harlow's

(1958) seminal work with infant monkeys, it has been understood that certain types of social cues and physical contact have intrinsically rewarding properties. In his studies, Harlow examined how infant monkeys preferred soft cloth surrogate mothers to wire mothers who fed them with milk. Over the years researchers, including Hofer, have examined these processes in great detail. For example, infant rats prefer smells associated with strokes from an artist's brush (Sullivan et al. 1986), warmth stimulates pups' activity levels (Hofer 1995), and milk appears to regulate pups' heart rates. Hofer has concluded that many physiological, behavioral, and affective systems are sensitive to particular stimulus properties of physical contact during development. These *hidden regulators* tone the physiology and behavior of the pups in ways that extend into the future. For example, licking and grooming, high-arched back nursing, and time in contact are associated with blood pressure throughout the life span. Female rats raised by dams with high levels of licking and grooming behavior are quicker to instigate maternal behavior in the presence of pups, and pups whose dams engage in higher levels of licking and grooming tend to be less fearful and have healthier stress profiles (Francis and Meaney 1999). Furthermore, those individuals also have greater numbers of oxytocin receptors in the medial preoptic area of the brain and in the lateral septum, amygdala, and hypothalamus (Champagne et al. 2001).

One important set of neuropeptides that have been somewhat overlooked in the literature on attachment are the endogenous opioids (Machin and Dunbar 2011). The brain opioid theory of social attachment (c.f., Panksepp 1998; Liebowitz 1983) comes from the observation that opiate addicts have strong similarities to people who are in love. Opioids are involved in the consummatory or termination phase of basic motivated behaviors (Bowlby 1969/1982; reviewed by Beckes and Coan 2013). During this phase, opioids reach peak levels, producing feelings of euphoria, satiation, and well-being (Nelson and Panksepp 1998). Further, opioids are known to be powerful analgesics, reducing physical and social pain rapidly, and they are believed to mediate the effects of pain reduction through social contact (e.g., Cohen et al. 2010; D'Amato and Pavone 1993). Thus they may be the best candidate mechanisms for brain mediation of the relationship between responsiveness and felt security.

In humans, the neuropeptides supporting the link between social contact and felt security are less well established, but social contact is known to decrease stress, threat response, and pain perception (Beckes and Coan 2011; Cohen et al. 2010; Coan et al. 2006; Eisenberger et al. 2011; Master et al. 2009) similar to what one would be predicted from the opioid theory. Liebowitz (1983) argued that relationships have three stages that are highly similar to those experienced by opiate addicts. The first stage is associated with euphoria and subsequent addiction, which parallels early-stage romantic love. The second is characterized by tolerance-habituation in which the intense feelings of euphoria are replaced by a baseline maintaining dependence. Similarly, young love gets replaced with a calmer attachment and greater interdependence. Finally, when the drug is no longer used or available, addicts experience withdrawal symptoms that mirror the grief process.

Although compelling, this hypothesis has yet to be definitively supported in humans. Still, some human studies have shown a clear connection between social contact and downregulation of threat and stress. In a study that directly tested the stress reducing benefits of social contact, Coan et al. (2006) scanned married women to see if holding hands with their spouse, or a stranger, would reduce their threat responses to a possible shock, relative to when they were threatened alone. There was a clear reduction in threat response in conditions in which the women held someone's hand. Moreover, that effect was larger in the spousal hand-holding condition than the stranger condition, and the effect was most pronounced in women with the highest quality relationships. Similarly, Eisenberger and colleagues (e.g., Eisenberger et al. 2011; Master et al. 2009) have found that participants have decreased neural pain responses when viewing photos of attachment figures. Thus, social contact does appear to lead to less threat response, supporting the notion that responsiveness-related behaviors can reduce threat and instill a sense of felt security.

The Combination of Threat and Responsiveness—A Security Cocktail

Thus far we have shown evidence for each individual piece of the argument that threat and responsiveness facilitate secure attachments. There is sparse but growing evidence that feelings of attachment security can be fostered through this mix of stimuli. Perhaps the most direct evidence comes from a set of studies by Beckes et al. (2010) who conducted a conditioning experiment to test this hypothesis directly. These studies involved implicitly backward pairing a negative unconditioned stimulus (US), either a photo of a striking snake or a mutilation scene, or a neutral US, such as a rolling pin or picnic basket, with conditioned stimuli (CS) in the form of faces with either neutral or warm, smiling expressions. After repeated iterations of the pairing of US followed by CS these researchers tested the effects of the pairings using the CS faces as primes in a lexical decision task for words associated with attachment security and insecurity. They found that warm, smiling faces paired with negative unconditioned stimuli routinely facilitated recognition of secure words and interfered with recognition of insecure words, whereas no such effects were found for neutral faces, or faces paired with neutral unconditioned stimuli. They concluded that both the negative stimuli and the cues of social responsiveness in the faces were necessary to increase associations between the novel faces and security concepts.

Recently, Beckes et al. (2013) found evidence that an early event-related potential component, the P1 component, which has been associated with approach-motivated attentional bias to ingroup members (Cunningham et al. 2012) is increased to smiling faces that were previously paired with striking snake images. Further, the difference in the P1 to snake-paired and rolling pin-paired faces predicted the

inhibition of response times to insecure words in a lexical decision task. Other studies support this hypothesis as well, either through marital interventions (Johnson et al. 2013) or developmental associations with the social regulation of emotion (Coan et al. 2013). For example, Coan et al. found fMRI evidence that maternal supportiveness in mid-adolescence predicted the threat reduction benefit received from holding a friend's hand 8 years later. Specifically, maternal engagement during a supportive behavior task in which the adolescent discussed a problem with which they were struggling predicted the adolescent's ability to receive the benefits of social contact with friends under threat in adulthood. This points to the likelihood that their mother's supportiveness in times of distress led to greater ability to capitalize on social support later in life, providing naturalistic and longitudinal support for the idea that security grows out of a distress-relief sequence. Johnson and colleagues (Johnson et al. 2013) demonstrated that emotionally focused therapy, based on attachment concepts, changed the neural profile of threat responding during hand-holding in distressed couples. This therapeutic intervention involves the primary components of threat and responsiveness by opening the emotional wounds of one member of the couple, and teaching the other to be responsive to that pain. Functional imaging before and after the intervention indicated that hand-holding before therapy was associated with greater threat response, whereas hand-holding after therapy was associated with a marked decrease in threat response, relative to threat response in the alone condition.

Taken as a whole, the evidence is strong that attachment security is sensitive to the distress-relief dynamic, and consistent responsiveness to distressing situations promotes a sense of security in a close relationship. Further, we have good leads on the neurochemistry that supports this dynamic, with evidence that oxytocin promotes affiliative motivation and is stimulated by stressful circumstances, and evidence that endogenous opioids are stimulated by social contact and downregulate the stress response.

From the Absence to the Presence of an Attachment Bond

A clear difficulty in understanding the nature and formation of attachment bonds is the slow developmental progression that such bonds undergo. Although evidence for an association between secure attachment associations and the distress-relief dynamic (e.g., Beckes et al. 2010, 2013) is useful and informative, such associations do not demonstrate the formation of a true attachment bond. Whereas feelings of security may be important in the formation of attachment bonds, they are not the same as an attachment bond. Further, ascribing a bond to such feelings in the absence of other indicators would ignore qualitative differences in relationships and the important fact that many people have insecure bonds, suggesting that bonds can occur between individuals in which contact after a stressor is not associated with easy relief.

Given these challenges it is important to understand what features of adult attachment relationships are capable of distinguishing between a general attraction to, fondness for, or sense of comfort with another, and a true attachment bond. Bowlby (1969/1982) described four primary behavioral features of attachment relationships: proximity seeking, secure base behaviors, safe haven activities, and separation distress. By necessity, the best feature to use as a measure of an attachment bond is one that is relatively unique to attachment relationships. Proximity seeking, or the degree to which an individual seeks out physical proximity to a specific other, is difficult to use as a discriminative behavior because adults seek proximity to others for many reasons including general attraction. Secure base behavior, or the degree to which the individual regulates his or her exploratory behavior, also becomes problematic in adults given the relatively greater degree of independence and potentially long latencies adults may use when returning to their secure base. Safe haven activities, or the degree to which individuals seek out a specific other when in distress, may be similarly difficult to use as a measure because of adult independence and a greater tendency to seek support from more specialized sources as a function of a particular friend, partner, or acquaintances' skills and affordances. Separation distress, however, may be particularly useful in this regard, and it has frequently been identified as the strongest indicator of an attachment bond (e.g., Bowlby 1980; Fraley and Shaver 1999). Separation distress in infants is commonly measured as protests and cries when separation from an attachment figure occurs. In adults, however, such protests are less likely unless the separation is thought to be permanent or of considerable duration. Another way of measuring separation distress is via biological signatures related to the coregulation of physiological systems (Sbarra and Hazan 2008) that become dysregulated after separation due to the removal of "hidden regulators" (Hofer 1995).

Coregulation and Bond Formation

The concept of coregulation may be the key to identifying whether a relationship constitutes a true attachment bond. Coregulation refers to the manner in which relationship partners' physiology becomes conditioned to the presence of the other. Sbarra and Hazan (2008, p. 143) define coregulation as "the reciprocal maintenance of psychophysiological homeostasis within a relationship." In humans there is a relatively sparse literature regarding the mechanisms that produce coregulation in relationships. Sbarra and Hazan (2008) have presented a coherent theoretical framework that relies on a combination of literatures across human and animal investigations. According to this model, attachment bonds emerge from reinforcement learning via various types of social interaction. The distress-relief dynamic refers specifically to the negative reinforcement side of this learning in which the attachment figure becomes associated with the reduction of distress and removal of painful, fearful, or otherwise threatening stimuli. Other types of learning, such as positive reinforcement, may support bond formation in addition to negative

reinforcement. For example, sex, play, and other positive interactions lacking the component of distress may serve to form an attachment bond by conditioning physiological coregulation with the partner. Over time, the consistent presence of the partner, regular social and sexual contact, and physical touch may tone various physiological systems, such as the stress system, to the presence of the partner. Separation from the partner can then lead to changes in those systems, manifesting psychologically as separation distress.

Neurobiological Processes in Bond Formation.

Oxytocin and endogenous opioids are likely important neural mechanisms involved in bond-formation reinforcement processes. As discussed above, they may be critical in the distress-relief dynamic, but their properties make it reasonable to assume that their action is central to bond formation as well. Oxytocin is associated with a variety of social behaviors including maternal behaviors, sexual behaviors, and social bonding (e.g., Lim and Young 2006). Central administration of oxytocin in animal models is sufficient to affect maternal behavior and pair-bonding (e.g., Keverne and Kendrick 1994; Pederson et al. 1982; Williams et al. 1994), and in humans oxytocin is associated with maternal behaviors following childbirth (Feldman et al. 2007). Opioids are strongly associated with reinforcement across social and nonsocial domains (see, Panksepp 1998). During sexual behavior, opioids are known to increase (e.g., Szechtman et al. 1981). Opioid antagonists prevent the development of partner and place preferences (Pfaus 2009). Critically, opioids diminish stress and pain responses (e.g., D'Amato and Pavone 1993), providing a potentially direct mechanism through which physiological systems become conditioned to an attachment figure and through which coregulatory processes develop.

One way in which various reinforcement processes could lead to an attachment bond is through the conditioned inhibition of stress in response to the partner's perceptual characteristics. In prairie voles, stress hormones such as corticotropin-releasing hormone (CRH), involved in the stress cascade via the hypothalamic-pituitary adrenal axis (HPA-axis), are associated with facilitated pair-bonding (e.g., DeVries et al. 2002). Other stress indicators, such as corticosterone levels, tend to increase upon separation and diminish upon reunification (Carter 1998). This finding, that HPA activity is greater upon separation from a partner, is consistent across various social mammals, hinting that social proximity to an attachment figure conditions diminished HPA-axis activity (Hennesy 1997; Mendoza and Mason 1997). Similarly, social support may desensitize brain regions involved in the detection and appraisal of threat, such as the dorsal anterior cingulate cortex (dACC), via the regular release of opioids (e.g., Eisenberger et al. 2007), offering another pathway through which social contact inhibits and conditions diminished stress response. Critically these features of attachment bonds are present even in insecure relationships. A history of sex, play, physical touch, and consistent proximity is probably sufficient to condition oxytocinergic and opioid systems to the presence

of the partner. These systems diminish threat reactivity and stress systems broadly, so separation from an attachment partner is likely to increase the individual's threat and stress responses to negative events.

Reinforcement Schedules and the Development of Attachment Styles

An important observation about the role of oxytocin and opioids in social bonding is that they are involved not only in negative-reinforcement occurring as part of the distress-relief dynamic, but also in positive reinforcement during a variety of other social behaviors such as sex, rough and tumble play, and caregiving (see Panksepp 1998, for a review). Thus, if they are involved in both the development of attachment bonds *and* attachment styles, the type of reinforcement that occurs, its frequency, and its predictability may be critical for which style emerges, explaining why insecure bonds develop. From our perspective the negative reinforcement aspect of the distress-relief dynamic may be central to determining attachment style in a manner in which positive reinforcement processes may not. Differences in the variability and predictability of the distress-relief negative reinforcement process may lead to distinct attachment qualities, leaving open the possibility that bonding and attachment style emerge from many of the same neural substrates acted upon via different stimuli or degrees of consistency.

Emergence of Insecurity in Attachment Bonds

Attachment anxiety may emerge out of inconsistent responsiveness in which the responder only sometimes responds, or responds only after persistent proximity and reassurance seeking (Mikulincer and Shaver 2003). Mikulincer and Shaver argue that when responders are not available, attentive, or responsive, but proximity seeking is a viable strategy, individuals will turn to a "hyperactivating" strategy associated with attachment anxiety. Hyperactivation is characterized by excessive reassurance seeking and needy behavior. Interestingly this hyperactive seeking for the negative reinforcement properties of the responder may be a function of random or variable reinforcement schedules. Because the partner sometimes responds effectively, and at other times does not, the reward becomes unpredictable. As Skinner (1956) discovered, consistent reward can lead to the extinction of the rewarded behavior, in this case proximity seeking, because of satiation. However, when reinforcement follows a variable schedule in which reinforcement is unpredictable, a behavior can become resistant to extinction, and in some cases can increase in frequency. Thus, security may be associated with a sense of reward predictability and the seeking behavior becomes contingent on need, circumstance, and internal state.

Alternatively, anxiety may be associated with unpredictability in the reinforcement schedule, producing hyperactivated behaviors toward the attachment figure.

Avoidant attachment is thought to emerge in response to consistently unavailable and unresponsive partners (Mikulincer and Shaver 2003). Mikulincer and Shaver argue that a strategy of "hypoactivation" develops in this case. Hypoactivation involves distancing oneself from threat, relying on self-regulation to cope with stressors, and ignoring or avoiding attachment-related cues. It is unlikely that any attachment bonds form completely absent of the distress-relief dynamic. Avoidant attachment likely emerges in the presence of an indirect form of distress-relief in which the individual learns to maintain proximity to the attachment figure, but also learns not to directly seek out support, maintaining an optimal proximity to the caregiver that provides relief, but does not trigger the punishment associated with rejection and inadequate responsiveness (Simpson et al. 2007). Moreover, after such a bond has been established, and the partners are actively coregulating each other, the distress-relief dynamic necessarily applies to these relationships. If separation leads to physiological dysregulation and reunification reestablishes normal regulatory function, then the mere presence of the attachment figure will provide distress relief. Thus, even in highly avoidant individuals, negative reinforcement is likely part of the attachment process.

Notably, however, the reinforcement of support seeking behavior will be absent due to punishing or never reinforcing direct support-seeking behaviors. Thus proximity in a more general sense is reinforced, but direct support seeking is not. This, however, does not require that the initial bonding process is largely driven by the distress-relief dynamic. This is highly speculative, but a possibility given animal models of pair-bonding (Carter 1998).

Sexual contact may produce a type of intimacy that at first is both stressful and rewarding, as is indicated by increases in stress hormone output during sexual encounters in prairie voles (DeVries et al. 2002). Because sex usually requires intimate contact, vulnerability could be an integral part of sexual contact for many individuals. In this sense, sexual encounters may be composed of a form of distress-relief dynamic when normatively experienced. Thus, avoidant individuals may form bonds with sexual partners despite either never directly seeking the partner out for support in stressful situations, or learning not to directly seek support because of the punishment associated with an unresponsive partner.

A Neurobiologically Based Model of Security Development

Of importance for those who wish to improve the quality of relationships through insights from attachment literature, the processes that promote security are of particular interest. From current evidence and logic, one can hypothesize a model of the neurobiological processes that promote the development of a secure attachment bond to a specific partner (see Fig. 2.1). Further, the model also can be used to

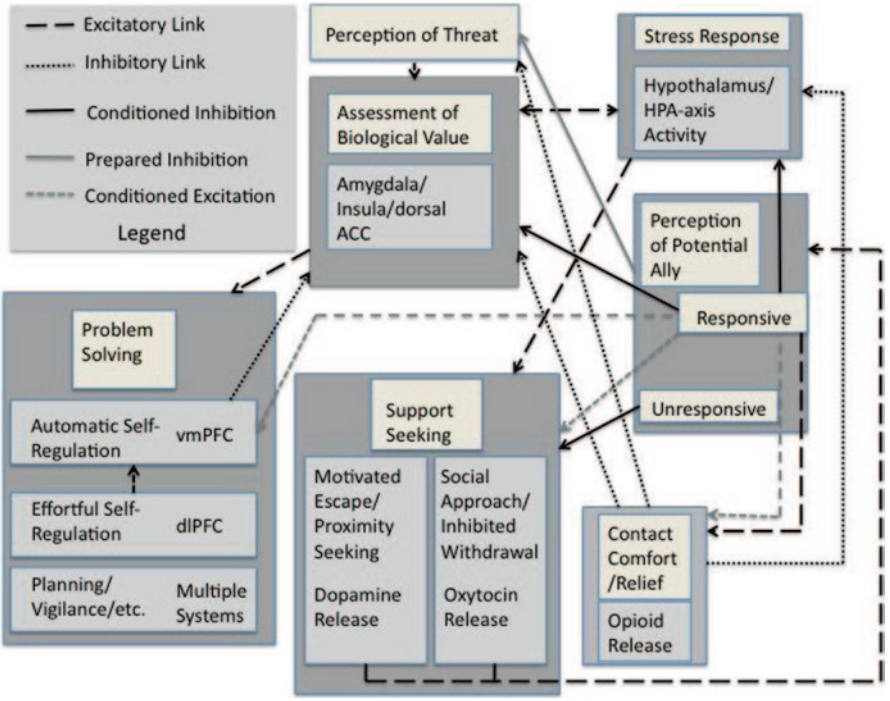

Fig. 2.1 Model of the distress-relief dynamic with psychological processes mapped onto neurobiological substrates and their linkages. The process begins with perception of threat, which activates threat responsive brain regions. From there a stress cascade is initiated in the hypothalamus and brainstem, along with the engagement of prefrontal systems for problem solving. These, in turn, initiate oxytocin and dopamine release to promote support seeking, which will lead to diminished distress via endogenous opioids if the individual perceives a responsive ally

predict both quantitative and qualitative differences in the degree to which close others regulate stress relative to less well known others.

It is clear from numerous studies of threat responding that the perception of threat leads to a cascade of activity in a network of brain regions (Coan et al. 2006, 2013). It is likely that the perceptual information first activates areas such as the amygdala and dACC, which begin to process the biological value of the stimulus and act as a neural alarm bell for other regions of the brain (Adolphs 2010; Bush et al. 2000). The amygdala immediately engages the HPA-axis via projections to the hypothalamus, initiating a cascading stress response (e.g., Gray et al. 1989).

Various regions of the cortex, such as the ventromedial prefrontal cortex (vmPFC) and dorsolateral prefrontal cortex (dlPFC) are activated in an effort to solve various problems associated with the emerging threat, such as the need to self-regulate (Poldrack et al. 2008). Additional activations occur as a way of monitoring the evaluative meaning of the stimulus in regions such as the orbitofrontal cortex (OFC; Damasio 1996), and actual and anticipated changes in the body via regions such as the insula (Craig 2009).

There is now some evidence that activation of the HPA axis will elicit both oxytocin release (Onaka 2004), potentiating social receptivity, and dopaminergic activity in the ventral striatum (e.g., Wanat et al. 2008), possibly potentiating motivated escape and/or social proximity seeking. In particular, oxytocinergic activity is thought to improve social perception (e.g., Jack et al. 2012), diminish social fear (e.g., Domes et al. 2007a), benefit "mind-reading" (e.g., Domes et al. 2007b), and motivate social approach (e.g., Kemp and Guastella 2011). This potentiation of social receptivity then heightens the perception of social others as responsive to the person's needs, instigating opioid release to responsive social contact (Machin and Dunbar 2011). Opioids inhibit threat responsiveness by downregulating activity in regions such as the dACC and HPA-axis (Nelson and Panksepp 1998). The consistent association of perceptual characteristics of the partner with downregulation of threat response and HPA-axis activity then conditions an inhibitory link between the partner's perceptual characteristics and threat responsive brain regions.

These inhibitory links could be supported through multiple pathways, including (a) excitatory associations between the perceptual characteristics of the partner and the vmPFC, which can downregulate threat-responsive brain regions (Eisenberger et al. 2011); (b) conditioned facilitation of the links between perception of the partner and opioid systems; (c) conditioned facilitation of the link between perception of the partner and oxytocin systems; and (d) conditioned links between the perception of the partner and threat response through the facilitation of relatively direct linkages. Additionally, support-seeking behavior is reinforced, increasing the association between the partner and social receptivity. Consistent responsiveness leads to a well formed association that is dependent on physiological homeostasis, whereas variable responsiveness may create stronger associations leading to constant reassurance-seeking through a form of chronic social deprivation. Nonresponsiveness, alternatively, may weaken this link, leading to greater reliance of self-regulation and avoidance of direct support seeking.

This model has several implications if correct. First it predicts quantitatively greater threat reduction in the presence of a consistently responsive partner. Indeed evidence from Coan and colleagues (e.g., Coan et al. 2006; see also Coan et al. 2013) supports this contention through findings that spouses are associated with less threat responding than strangers, and the degree to which that is the case is moderated by relationship quality. Further, the model implies a qualitative difference in threat and stress responding for individuals with consistently responsive partners. First, consistent positive social contact should potentiate greater opioid activity in general, an idea Nelson and Panksepp (1998) refer to as opioid tone. Greater opioid tone should lead to generally less threat responding as long as opioid tone is maintained. Additionally, the conditioning of the partner to reduced HPA-axis and threat response activity should not only strengthen the link between perception of the partner and diminished stress response, but could, over time, condition the individual's stress response to the partner, leading to coregulation of this system. In this case, separation distress becomes more likely. From this, one might predict increased HPA activity in situations in which the partner is known to be unavailable for support. Indeed, this facet of the model is what most clearly separates

attachment relationships from nonattachment relationships in that it indicates a dependence on the other person for regulation of the individual's stress system.

Conclusion

Many components of the psychological literature suggest that distress and responsiveness are intimately linked with bond formation, stress reduction, and a sense of security in relationships. A small but growing body of evidence suggests that the distress-relief dynamic is critical in the development of secure attachments through negative reinforcement conditioning. Importantly, attachment security and its associated feelings are not the same as an attachment bond. Bonds may be formed via positive social interactions such as sex or play through positive reinforcement processes. Yet, positive reinforcement may lead to little information regarding the availability, attentiveness, and responsiveness of a given relationship partner. Without this information a sense of security cannot develop. Thus, various reinforcement processes may help to create a bond, but it is likely that only negative reinforcement strongly influences the security of that bond. Further, as a bond develops, even one that is built largely on positive reinforcement processes will eventually yield to the distress-relief dynamic and negative reinforcement processes as members of a relationship begin to coregulate each other.

This argument provides some possible directions to explore how and why particular attachment styles develop. For example, we argue that inconsistent responsiveness may lead to anxious attachment strategies through resistance to extinction of the proximity-seeking response. Variable reward schedules may intensify and maintain proximity seeking even in the presence of an acute reward; thus predictability may be critical for the extinction of proximity seeking and a sense of security that the attachment figure will be there when needed. Alternatively, avoidance may emerge out of a relative lack of negative reinforcement or even the presence of punishment when seeking out direct support. This is not to imply that negative reinforcement is not critical to these relationships, but rather direct support-seeking strategies for achieving that negative reinforcement are not sustained (or in adulthood they may never be adequately attempted in light of previous learning). Thus, proximity may be soothing for an avoidant person, but support may be sought in a less direct manner.

Additionally, oxytocin and endogenous opioids may be critical neurobiological substrates for these processes. We argue that oxytocin is most likely involved in the organization of proximity-seeking motivation and behavior by motivating social approach and sensitizing social perception processes. Opioids are likely involved in the reinforcing properties of social context, and when they are paired with social contact and physiological arousal due to distress, the perceptual characteristics of the partner become linked with downregulation of stress systems. Over time the stress system becomes conditioned to the presence of a partner resulting in coregulation, which we argue is the hallmark of an attachment relationship. Many of the health and well-being benefits commonly associated with close relationships may

be supported through coregulation, which moderates the stress system. This chapter provides a detailed model of how this process might occur, providing the necessary connections and predictions to guide further investigation of the neurobiological and psychological foundations of attachment and security.

Future investigations should further explore several key aspects of the model presented here. First, more evidence concerning the links between stress, oxytocin, and support seeking is needed to fully validate the idea that stressors often promote oxytocin release and in turn support proximity-seeking behavior. Second, the links between feelings of security, stress reduction, positive social contact, and opioid release need to be further explored, particularly in humans. For example, investigations should determine whether opioids are necessary for the stress-reducing benefits of social contact. Third, research should explore whether a history of security and responsiveness in an attachment relationship leads to decreased threat perception in the presence of that attachment figure, and whether that process occurs in a bottom-up perceptual manner and/or through cortically mediated processes. Fourth, the degree to which negative reinforcement is necessary for security should be further explored. Such investigations could, for example, determine whether proximity-seeking behavior is heightened in the context of a variable reinforcement schedule, and whether security is associated with extinction due to consistent and predictable responsiveness. Fifth, more research on the establishment of coregulatory patterns in relationships over time and the impact of separation should be top priorities for the field.

Exploring these questions further and sharpening our models at multiple levels of analysis will lead to increasingly well honed abilities to predict outcomes for attachment relationships and develop potential interventions. Due to the benefits of close personal relationships for health and well-being, a better understanding of both the normative psychological and neurobiological processes supporting attachment bond formation and attachment quality formation would be a great boon to both science and society.

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