Apart from primary physiological needs, social relationships may be the most powerful factor related to human health and well being. Social isolation brings emotional pain and increased risk for illness and death (House, Landis, & Umberson, 1988) while proximity to rich social networks attenuates stress-related autonomic and hypothalamic-pituitary-adrenal (HPA) axis activity (Eisenberger, Taylor, Gable, Hilmert, & Lieberman, 2007; Flinn & England, 1997; Lewis & Ramsay, 1999), and lowers risk for both physical and psychological maladies (Moak & Agrawal, 2010). These positive effects are particularly pronounced within the context of high-functioning romantic and family relationships characterized by high levels of trust, positive affect and interdependence (Coan, Schaefer, & Davidson, 2006; Kiecolt-Glaser, Glaser, Cacioppo, & Malarkey, 1998; Robles & Kiecolt-Glaser, 2003). Indeed, when close personal relationships rupture, the negative emotional and physiological sequelae can be catastrophic (Sbarra, Law, & Portley, 2011). Although there are likely to be many mechanisms linking social relationships to health, a major factor is the provision of perceived resources—a perception that can literally make the world look less demanding (Schnall, Harber, Stefanucci, & Proffitt, 2008), and safer (Coan, et al., 2006). That is, when we perceive ourselves to be embedded in a rich social network, we tend to believe that the resources of the network are resources the network shares with us, which allows us to adjust our level of personal effort accordingly. Humans have
a unique and powerful ability to forge and maintain networks of social interdependence characterized by shared goals, joint attention and cooperative, even altruistic behavior (Herrmann, Call, Hernandez-Lloreda, Hare, & Tomasello, 2007). We think of the regulatory effects of social relationships as a major human adaptation—one that forms part of the foundation of the human habitat, which can itself be found, more than any specific terrestrial niche or diet, in the company of other humans.

**The Prefrontal Cortex is Powerful and Costly**

The human prefrontal cortex provides humans with a distinct advantage over other animals. Across a wide variety of contexts, humans are capable of anticipating future rewards, planning detailed contingencies, thinking in abstractions, executing very complex communication and controlling of our impulses and emotions. Indeed, humans are even capable of using prefrontal processing to soothe themselves in a variety of ways and for a variety of purposes, as when, for example, we tell ourselves that the violence we are observing is only a movie (Gross & Thompson, 2007). Moreover, individual differences in these capabilities are highly consequential. In children, the ability to inhibit emotional impulses—as when gratification is delayed—is associated with a host of early social, cognitive and academic advantages (Mischell, Shoda, & Rodriguez, 1989), fewer externalizing problems such as aggression, conduct disorder, and oppositional defiant disorder (e.g., Crowe & Blair, 2008; Beauchaine, Gatzke-Kopp, & Mead, 2007; Hill, Degnan, Calkins, & Keane, 2006; Rydell, Berlin, & Bohlin, 2003), and decreased risk for affective disorders (Buckner, Mezzacappa, & Beardslee, 2009; Dennis, Brotman, Huang, & Gouley, 2007). Effective self-regulation is no less beneficial to adults, where it is similarly associated with enhanced life satisfaction, decreased affective psychopathology, happier relationships and better overall health (Haga, Kraft, & Corby,
Many psychotherapeutic interventions emphasize self-regulation. In particular, cognitive behavioral therapy and mindfulness meditation help individuals develop their capacity to regulate their own emotional responses (Lykins & Baer, 2009; Smyth & Arigo, 2009; Suveg, Sood, Comer, & Kendall, 2009).

Human self-regulation capabilities are so powerful that we find it is useful to think of humans as the cheetahs of self-control. Just as the cheetah is the Earth’s fastest land animal (capable of reaching speeds of up to 75 miles per hour!) no other species on the planet is capable of crafting a regulatory cognition that even approximates the phrase “it’s only a movie.” Less appreciated, however, is that the cheetah analogy extends to another important aspect of self-control: that its use is constrained by the perception of available resources. Just as the cheetah can only sustain its top speed for short bursts of time, human self-regulation abilities are difficult to sustain for long periods (Gailliot, & Baumeister, 2007). Several experiments by Baumeister and colleagues suggest that self-control depletes some kind of computational or physiological resource. In these experiments, the deployment of self-control in one situation appears to decrease or compromise its use in another. For example, when compared to simply solving math problems, engaging in a thought-suppression task makes people more likely to drink a free alcoholic beverage before a driving evaluation (Muraven, Collins, & Nienhaus, 2002). Some have argued that this limitation is a function of blood glucose concentration, which is thought to diminish as a function of neural—particularly prefrontal—activity (Galliot & Baumeister, 2007). This isn’t likely. First, blood glucose levels in the brain probably do not change enough during self-control tasks to account for the apparent depletion effects that many have observed (Kurzban, 2010). Second, simple experimental manipulations—such as presenting subjects with a gift (Tice, Baumeister, Shmueli, & Muraven, 2007) or simply persuading subjects that
willpower is an unlimited resource (Job, Dweck, & Walton, in press)—can apparently reduce or eliminate these depletion effects.

All of this suggests to us 1) that self-control is indeed costly (or depletion effects would not so commonly obtain); 2) that the cost of self-control is unlikely to be a function of a specifically proximal resource limitation (meaning that apparent depletion effects can in essence be overridden when needed); 3) that in any case, because self-control is apparently costly in some important if poorly understood way, the brain tends to avoid engaging in self-control efforts whenever possible; and 4) that the brain probably reflexively uses a variety of heuristic cues to decide when it is reasonable to conserve its regulatory capabilities instead of deploying them. In this way, rather than being beholden to a specific quantity of a metabolic resource (like glucose, cf., Galliot & Baumeister, 2007) the brain is probably designed to update its “budget” for self-regulatory resources, with an eye toward conservation, as we move through our uncertain world. Budgeting is a broad principle of how the human body manages its resources. This is why we feel hungry and eat long before we are in danger of starvation, and why we feel fatigued long before we run out of metabolic resources—even when engaged in a physically demanding task, like running a marathon (Noakes, 2012; Swart, Lindsay, Lambert, Brown, & Noakes, 2012). We will argue below that one of the human brain’s primary sources of information for economizing its cognitive and regulatory activity is the degree of proximity to social resources (Beckes & Coan, 2011; Coan, 2008). We will frame our argument in terms of our own empirical work, and a conceptual frame borrowed from behavioral ecology and the study of perception/action links.
Social Regulation of the Neural Response to Threat

Many mammals regulate emotion through social contact and proximity (Fogel, 1993). Social contact exerts a significant impact on health and well being, enhancing immune functioning (Lutgendorf, Sood, et al., 2005; see, Uchino, 2006, for a review), minimizing salivary cortisol responses (Turner-Cobb, Sephton, Koopman, Blake-Mortimer, & Spiegel, 2000), lowering resting blood pressure (Uchino, Holt-Lunstad, Uno, & Bettancourt, 1999), and decreasing risk of carotid artery atherosclerosis (Knox, Adelman, Ellison, Arnett, Siegmund, Wiedner, & Province, 2000). Higher levels of social integration even reduce age-adjusted risk of death (House, Landis, and Umberson, 1988).

Our lab has begun to systematically explore social affect regulation using functional magnetic resonance imaging (fMRI). In the first of these studies (Coan, et al., 2006), functional brain images were collected from 16 married women, selected for very high marital satisfaction, who we placed under the threat of mild shock during each of three conditions: holding the hand of their relational partner, holding the hand of a stranger, or lying alone in the scanner. We were interested both in the subjective experience of unpleasantness and arousal during these tasks and any modulations of the brain’s threat response as a function of handholding. Self-reported unpleasantness was indeed lowest during partner hand holding condition, relative to either stranger hand holding or no hand holding, while both stranger and relational partner hand holding reduced subjective arousal relative to the alone condition.

Analyses of threat related brain activity suggested that the brain was highly active when threats were faced alone, significantly less active during either stranger or partner hand holding, and least active during partner hand holding. Specifically, regions of the brain involved in the modulation of arousal and bodily preparation for action, such as the ventral anterior cingulate
cortex (ventral ACC), posterior cingulated cortex, postcentral gyrus, and supramarginal gyrus, were all less responsive to threat cues during any hand holding. But partner hand holding also attenuated threat responding in the dorsolateral prefrontal cortex, superior colliculus, caudate and nucleus accumbens—all regions associated with threat vigilance and self-regulation.

Given that the sample consisted of highly satisfied couples, it was surprising that relationship quality (as measured by the Dyadic Adjustment Scale, or DAS, Spanier, 1976) was negatively correlated with threat responding in brain regions critical to the status and regulation of the body in response to stress, such as the right anterior insula ($r = -.47$), the left superior frontal gyrus ($r = -.59$), and the hypothalamus ($r = -.46$). More surprising still was that these negative correlations were only observed during the partner hand holding condition. Taken together, these findings provide strong evidence that most threat-responsive brain areas are less active when experiencing physical contact with another person. Moreover, the effect is larger and more widespread when that other person is a relational partner, and it is larger still among individuals in the highest quality relationships.

The Down Regulation Model

The down regulation model is in many ways the implicitly assumed model of emotion regulation, including social emotion regulation. This model postulates a regulatory circuit that inhibits circuits automatically responsive to the threat. In the context of the hand holding study discussed above, the down regulation model would suggest that 1) the threat cue activated a widespread threat system and 2) that hand holding activated an additional regulatory system that exerted an inhibitory influence on the already active threat system. For this model to be correct, of course, evidence for both systems must obtain, as well as evidence that activation in one is inversely proportional to activation in the other. Indeed, because additional regulatory effects
were observed as hand holders changed from strangers to familiar partners, and, within partners, from lower to higher quality relationships, it may be necessary to postulate additional down-regulatory mechanisms associated with these moderating variables.

If true, it is possible and perhaps likely that the brain would be most active when facing a threat while receiving support from a close relational partner with whom a very high quality relationship is shared. This is because both excitatory and inhibitory activity would necessarily occur more or less simultaneously across a variety of threat-responsive regions, an effect that would resemble pressing on the accelerator of a car while simultaneously pressing on the brake. Indeed, this is precisely the kind of effects one finds during self-regulation tasks, and this may in turn contribute to the fatigue self-regulation tasks frequently cause (Galliot & Baumeister, 2007). But what we actually observed did not resemble self-regulation. In fact, in the hand holding study described above, absolutely no neural circuits were identified that were, independent of the presence of a threat cue, simply more active during hand holding, during hand holding associated with a relational partner, or during hand holding as a function of relationship quality. The brain was simply more active when facing threat alone, relative to when facing threat coupled with social support. Thus, the down regulation model of social support has not been supported by our data.

**The Social Baseline Model**

The social baseline model questions the core assumption of the down regulation model by suggesting that the brain *assumes* proximity to social networks and relational partners (Coan, 2008). If this is the case, social proximity—not the alone condition—is closer to the brain’s baseline, and social support acts not by exerting a regulatory force so much as returning an organism to it’s baseline or default state. From this perspective, it is being alone that constitutes
the special case, not the social support condition, which is in fact normative. The social baseline model requires a seemingly subtle but actually powerful change of perspective, much like a figure-ground illusion. It encourages a change of focus from a process of decreasing threat sensitivity via social proximity to a process of increasing threat sensitivity by being alone—two perspectives that are no more identical than the famous Rubin vase and the two faces that frame it (Rubin, 1921). It is easy to implicitly expect that more is going on in a participant’s environment when they are with a close friend—especially during a threatening situation—because there are literally more perceivable stimuli with the friend included. But it may be that from the brain’s perspective, there are actually fewer perceived costs associated with the threat when the close friend is present, and this reduction in cost may lead the brain to simply take less action.

Indeed, the social baseline model appeals to the economy of action principle (cf., Proffitt, 2006), which states that organisms must consume more energy than they use in order to survive, an imperative that leads to the conservation of resources whenever possible (cf., Krebs & Davies, 1993; Proffitt, 2006). We already know that perception is not an entirely passive process, but rather is influenced by a number of factors—goals, emotions, physiological states—related to an organism’s situation (Proffitt, 2006). It is similarly true that an organism’s perceptions are closely aligned with its unique adaptations and, by extension, its unique environment. In this way, perceptions are tightly linked to the actions that environments afford. Proffitt and colleagues have argued that these perception-action links are often highly “economical” in the sense that they tend toward the optimization of return on investment. For example, individuals perceive hills to be steeper and distances farther away if they are wearing a heavy backpack. According to Proffitt, the bodily perception of the heavy backpack translates to increased
perceived physiological load, which causes a perceptual shift in the geographical features with which the individual must cope. All of this perceptual information updates the perceived cost of engaging in the corresponding actions—climbing a steep hill or walking a long distance. Thus, with increased weight to carry, the hill appears steeper, the brain perceives a greater investment in added tasks, effort, or both, and commensurably more motivation must be marshaled if the hill is going to be climbed. Put another way, without the backpack, a simple curiosity in what the top of the hill looks like may be sufficient to motivate climbing it. With the backpack on, however, simple curiosity might not provide sufficient motivation—a payoff commensurate with the additional cost is required. Because energy management is a critical aspect of daily living and a major pressure in evolution, organisms have evolved to calculate (in mostly implicit ways) the perceived cost/benefit ratio of any given action or investment of resources, including, we believe, self-regulation.

Social Baseline Theory (Beckes & Coan, 2011; Coan, 2010) suggests that for humans being alone is like carrying a heavy backpack. The fundamental premise of SBT is that, more than any specific terrestrial environment or diet, social proximity and interaction constitute the baseline human habitat, and that socially mediated regulatory influences are sufficiently powerful, widespread, economical, and unconditioned, to be considered the default human regulation strategy. From the perspective of SBT, just as salamanders are born with physiological (and obviously implicit) expectations of finding moist, cool, dark spaces to inhabit, humans are born with physiological, behavioral and psychological expectations of human contact through touch and affective expression—of individuals with whom to share resources, goals, attention, and regulation (Kudo & Dunbar, 2001; Sbarra & Hazan, 2008; Tomasello, 2009).
We use social cues to guide us in making decisions about the economy of certain actions, which in turn guides the activation of neural circuits commensurate with carrying out those actions. If social proximity is a baseline human situation, then less effort should be needed in terms of vigilance for potential threats and emotion regulation when we are actually in reasonably close proximity to individuals with whom we share familiarity, interdependence and trust. When it comes to emotion regulation in particular, our efforts may be normatively outsourced to close others who decrease our need for regulatory effort either by obviating the need for an affective response altogether or by engaging in regulatory behavior for us (e.g., by noticing our discomfort and holding our hand), effectively loaning us prefrontal cortex processing. This would allow us to achieve regulatory benefits at a greatly reduced cost. SBT refers to this process as load sharing and argues that it is largely a function of familiarity, interdependence, and interpersonal conditioning. With a moment’s reflection, it is very easy to illustrate and understand. If an individual is confronted with four problems in his immediate environment, then he must solve all of those problems himself if no one is there to help him. If a stranger is present, it may be that at least some of the load—say, a single one of those problems—can be “contracted out” to the stranger, leaving only three problems. If the social resource is familiar and predictable, the number of problems may reduce to two, and if the person is someone with whom a high quality relationship is shared, then only a single problem of the possible four may require solving independently.

Examples of social affect regulation are most obvious in infancy, where the regulation of physiological needs (hunger, thirst, warmth) is achieved through caregiver responses to the infant’s negative affect. As the infant develops through toddlerhood and beyond, however, the regulation of physiological needs via the child’s affect gradually evolves into the regulation of
the child’s affect per se (Hofer, 2006; Nelson & Panksepp, 1998). All of this occurs in a context of rich and rapid neural development within the infant brain, which, through these years, is characterized both by the rapid expansion and pruning of synaptic connections—a putatively (though not indisputably) critical period where the child is beginning to form expectations and implicit beliefs about the environment it can expect to face as it develops toward independence.

Importantly, one of the least developed regions of the brain immediately following birth is the prefrontal cortex—a broad region of the brain powerfully associated with self-regulation, including the self-regulation of emotion (Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner & Gross, 2005). Human infants are physiologically dependent upon adult caregivers, but even as they develop the means to be relatively independent, they continue to rely on adults for many years because of underdeveloped reasoning and regulatory abilities yoked to similarly underdeveloped prefrontal cortices. Thus, although a child of seven years is physically capable of navigating, for example, a cross-country trip on public transportation, most of us would not be willing to let her do so unaccompanied. The base of knowledge required for such a trip is minimal and probably well within her grasp, but we would not expect her to be particularly good at regulating her anxiety along the way, nor we would trust her judgment about how best to respond to unexpected dangers. According to SBT, adult caregivers assist with these needs by loaning their children prefrontal effort. If a child is incapable of regulating himself at a frightening movie, for example, his parent can hold his hand and do the regulatory work for him by reminding him that the action in the movie isn’t actually real, and that the child is any case safe because the parent will protect him. At both the experiential and neural levels, regulatory work is effortful and (as many parents well know) even potentially exhausting. This is because the parent is exercising her own prefrontal effort to maintain vigilance for the child’s state and to
respond to the child’s state with alternative interpretations of the situation—both activities that involve a great deal of cortical, including prefrontal, processing (Chudasama, 2011; Ochsner & Gross, 2005; Pardo, Fox, & Raichle, 1991).

**Mediating Mechanisms of Social Regulation**

As reviewed above, we do not think the down-regulation model does the best job of explaining the results of the previously reviewed hand holding study, because we did not observe any neural activations positively correlated with hand holding per se, and through which our social regulation effects were mediated. Nevertheless, there must be some mechanism capable of identifying the presence of conspecifics, particularly relational partners, as well as a mechanism linking the general perception of plentiful social resources to attenuated threat reactivity.

One obvious potential mechanism mediating the decreased responsiveness to threat during social contact is the neuropeptide oxytocin (OT). OT plays a central role in social behavior in a variety of species, including humans. Indeed, OT is released during pleasurable social contact, may be necessary for establishing and maintaining social bonds, particularly among monogamous species, and appears to be sufficient in many cases for increasing feelings of trust and inhibiting feelings of fear (Insel & Fernald, 2004; Taylor, 2006). These findings make it a natural candidate mechanism for the social regulation of neural threat responding. In fact, Kirsch and colleagues (Kirsch, Esslinger, et al., 2005) have reported direct evidence for OT’s role in the regulation of human amygdala function. Half their participants were given a placebo, while the other half were given OT via a nasal spray. Participants who received OT showed significantly less BOLD response in the amygdala to negative emotional pictures than those in the placebo condition, indicating a reduced threat response as a function of OT.
administration. This suggests that OT may reduce threat vigilance. Given OT’s tendency to release in the presence of social stimuli, social contact may reduce an individual’s need to self-regulate in a manner consistent with SBT. If this is correct, then people should rely less on their prefrontal cortex to regulate their emotion when social resources are high, and this should be mediated by increased OT activity in the amygdala and elsewhere.

Another possibility is that endogenous opioids, particularly in the dorsal ACC, inhibit activation of threat-related emotional responses in part by modulating threat detection. Eisenberger and colleagues (Eisenberger, et al., 2007) have observed that the dorsal ACC is highly sensitive to the availability of social resources, with important implications for how individuals respond to threatening stimuli. Specifically, Eisenberger et al. reported that higher daily levels of perceived social support were associated with lower levels of threat-related activity in the dorsal ACC. Although this is not direct evidence, these authors suggest that positive social experience may desensitize the dorsal ACC through repeated exposure to endogenous opioids. The dACC does in fact have a high density of opioid receptors, and endogenous opioids are unconditionally released in response to positive social experiences (Panksepp, 1998; Panksepp, Nelson, & Siviy, 1994). Moreover abundant evidence suggests that opioid activity inhibits both central and peripheral stress responses, not only in the midst of a perceived stressor, but also by a process of building “opioid tone” via opioid activity during non-stress states (Zubieta, et al., 2003). Although a detailed understanding of these potential mechanisms of social support awaits additional research, oxytocinergic activity in regions such as the hypothalamus, nucleus accumbens and amygdala, as well as endogenous opioid activity in the dorsal ACC, are exciting possibilities.
Summary and Conclusions

Human beings possess powerful attention and self-regulation capabilities, owing in large measure to their large and commensurably powerful prefrontal cortices, but sustained activation of these prefrontal capabilities is exhausting, and probably metabolically costly in ways that are only beginning to be understood. In any case, vigilance and self-regulation are likely to be most effective over relatively short periods of time, with longer-term demands resulting in steadily diminishing returns. Social contact and proximity appears to manage this potential problem by attenuating the demands for self-initiated attention and regulation. We have suggested that this dynamic creates a pressure to stay in close proximity to social resources, and that close social proximity is by extension a baseline state for human beings.

This line of thinking presents new opportunities for research and theory development. A critical prediction of SBT, for example, is that computational or metabolic resources devoted to attention and self-regulation are indeed conserved through social proximity and interaction. Although our initial hand holding/fMRI provides some glimpses of such conservation, future work should seek to test this position in more specific ways. For example, according to Baumeister and colleagues, we might expect smaller changes in circulating blood glucose following a stressful self-regulation task in the presence of active social support. Failing such a direct impact on circulating blood glucose (an uncertain and in any case disputed potential proxy measure of cognitive effort), stress may lead to greater consumption of resources (concretely, eating more food), reflecting a change in resource “budgeting” as a result of increased self-regulatory demand, all of which may be mitigated by reliable social support. Alternatively, it seems likely that self-regulation exerts a measureable negative impact on concomitant or
competing cognitive activities—one that might be offset by, again, close proximity to social resources.

SBT holds a number of implications for applied fields as well. It may be possible, for example, to develop a neural assay of social support by imaging the social regulation of hypothalamic activity during stress. Such information may lead to significant progress in predicting the effect of a person’s social support network on a variety of health outcomes, including response to medical treatment, risk of depression, and physical resilience to disease. Access to reliable social resources may prove critical in determining people’s abilities to manage pain related to arthritis, cancer treatment, and a variety of other health problems. Interventions could be used to potentiate the impact of social proximity, such as interdependence training for couples, or possibly social capital development for communities. More can be done to understand how social resources can be mobilized to reduce the stress and health impact of major life transitions such as going to college, becoming a parent, or beginning retirement.

Real world anecdotes point to the potential for social regulation. For example, in the midst of data collection for the original hand holding study, one participant exited the scanner in tears. When asked what was wrong, she reported that the combination of threat and soothing hand holding caused her to remember holding her husband’s hand during labor with their first child—a memory that brought her tears of joy. In another example, an individual who hadn’t participated in the hand holding study but had read about it in the popular press sent a letter to the laboratory describing her experience of coping with her husband’s cancer. In it, she noted that “he never holds my hand, it is not like him. But, after this surgery and all the time in the hospital, he constantly wants me to hold his hand. He reaches for me all the time.”
References


