SOCIAL NEUROSCIENCE

Biological Approaches to Social Psychology

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THE NEUROSCIENCE OF "EGO DEPLETION"

How the Brain Can Help us Understand why Self-control Seems Limited

Michael Inzlicht, Elliot Berkman, and Nathaniel Elkins-Brown

Self-control, known colloquially as willpower, refers to the mental processes that allow people to override any of their thoughts, emotions, or behaviors that compete with their overarching goals. At its heart, self-control is instigated when a person faces a conflict between two competing desires or response tendencies—say, when a dieter is conflicted between ordering a salad or a juicy hamburger for lunch; or when a writer is conflicted between putting pen to paper or checking her favorite social media websites; or even when a study participant is conflicted between naming the color of a word and reading the word in a Stroop task. Such conflict is experienced as subjectively aversive (Saunders, Milyavskaya, & Inzlicht, 2015) and can lead people to inhibit or suppress one set of desires or responses and replace them with the second set (Inzlicht, Bartholow, & Hirsh, 2015). Self-control is thought to be applied when a person chooses to inhibit and transcend their immediate desires (e.g., a juicy hamburger, Twitter, word-reading) and to replace them with behavior that is in line with their longstanding goals (e.g., healthy salad, writing, color-naming). As such, self-control is based on core executive functions (Hofmann, Schmeichel, & Baddeley, 2012), specifically inhibitory cognitive control (Miyake et al., 2000).

Self-control, then, helps people to stick to their jogging routine when it is raining outside, stay composed when their boss is yelling at them, and save money instead of making an impulsive purchase. Given the impressive array of behaviors it is thought to underlie, part of the excitement surrounding research on self-control is the promise of what it can uncover: By studying how self-control works, we can discover how to improve it (Inzlicht, Legault, & Teper, 2014). Indeed, a search for ways to improve people's self-control capabilities is an implicit (if not explicit) goal of much contemporary research on the topic. Many of us would like to know how to control our behavior more effectively, and reducing self-control to its basic psychological and neural operations will facilitate this.

Neuroscience may be a particularly effective lens to understand a construct as complex as self-control because it allows for explanations that penetrate surface differences and uncover mechanistic similarities. As chapters in this volume demonstrate, neuroscience-level explanations are excellent for breaking down and understanding psychological phenomena in terms of root processes and mechanisms. Because biological approaches to social psychology have the potential to measure social-psychological processes as they occur in real time, they can tap online processes without being tainted by retrospective memory biases; they can also tap processes that are implicit in nature and beyond conscious retrospection or control (Harmon-Jones & Winkielman, 2007; Kang, Inzlicht, & Derks, 2010; Ochsner & Lieberman, 2001). Most exciting, perhaps, is that measures derived from neuroscience are now at a point where they can meaningfully predict real-world outcomes, and thus complement more traditional measures (Berkman & Falk, 2013). This is especially the case for the neuroscience of self-control, where by connecting brain measures of self-control with self-control in the real world, we are gaining a deeper appreciation of what self-control is, how it works, and potentially, how to improve it (e.g., Berkman, Falk, & Lieberman, 2011).

In this chapter, we explore the psychology and neuroscience of self-control, focusing specifically on one of its important facets: its apparent refractory period. For some time, it has been known that self-control wanes after previous efforts at control, such that self-control appears to have some temporal processing limit (Baumeister & Heatherton, 1996; Muraven & Baumeister, 2000). The dominant account of this limit is that self-control is based on some finite resource or energy, such that engaging self-control quickly consumes this inner capacity and leaves one in a state of "ego depletion," with further attempts at self-control prone to failure (Baumeister, Vohs, & Tice, 2007). The resource account has been highly influential and has informed most subfields of psychology and human neuroscience, as well as the related fields of behavioral economics, organizational behavior, and consumer behavior. Despite its prominence, however, a thorough understanding of how and why self-control has an apparent refractory period has been slow to develop, and it is clear that more theoretical and empirical work is needed (Inzlicht & Schmeichel, 2012).

Here, we explore some issues in the psychology and neuroscience of ego depletion, in the hope that an understanding of how self-control is implemented in the brain can teach us how and why self-control has a refractory period. We start with an overview of the traditional resource model of self-control, and explore a number of empirical findings that are hard to reconcile with the resource account. Having conveyed the argument that this account may be lacking in explanatory and predictive power, we then search for answers in some of the still nascent but burgeoning literature on the neuroscience of self-control, and on the neuroscience of ego depletion in particular. This is then followed would like to know how to control our behavior more effectively, and reducing self-control to its basic psychological and neural operations will facilitate this.

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The Resource Model of Self-control

The resource model of self-control suggests that self-control is based on a kind of fuel that powers the will (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven & Baumeister, 2000). The resource model makes two major claims. First, it is claimed that self-control draws upon a shared, central resource which underlies a vast array of behaviors that may be different from one another, but each involves the inhibition of some pressing urge or impulse. Self-control, for example, fuels the ability to eat broccoli over chocolate. The second major claim of the resource account has garnered far more attention, and in recent years, has proven somewhat controversial (Inzlicht & Schmeichel, 2012; Kurzban, Duckworth, Kable, & Myers, 2013).

The second claim is that self-control is based on a limited resource or fuel that runs out after use. Thus, engaging self-control is thought to consume and deplete this limited inner capacity, leaving further control attempts underpowered. Just like your car consumes fuel to get from one point to another, until there is no more fuel and no more driving, the argument goes that you consume some limited resource to control your behaviors throughout the day until you reach a point where this resource is consumed, and you are left without the ability to control yourself any further.

The main evidence in support of the resource model comes from studies showing that exerting effortful control at some earlier Time 1 impairs self-control performance on a different task at some later Time 2. To date, over 200 studies have used this "sequential task paradigm" to support the notion that self-control is based on a limited resource (e.g., Hagger, Wood, Stiff, & Chatzisarantis, 2010). For example, staying calm under emotional duress has been found to make it more difficult to restrain from eating ice-cream, maintain items in working memory, and maintain physical stamina (Muraven, Tice, & Baumeister, 1998; Schmeichel, 2007; Vohs & Heatherton, 2000). Studies using this sequential task paradigm have suggested that self-control is limited and relies on a finite resource. To date, however, studies scrutinizing the precise processes via which self-control failure in the sequential task

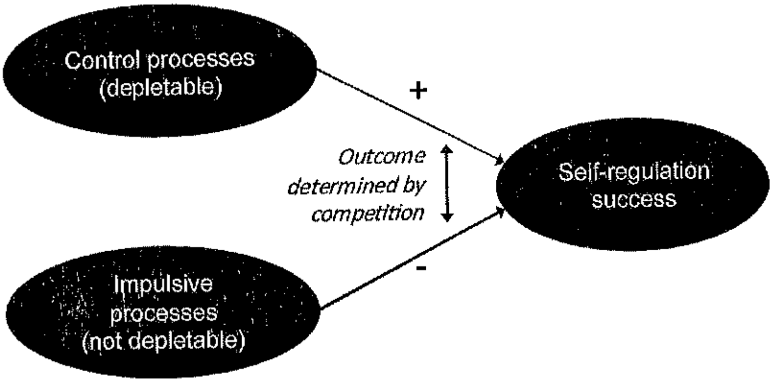

FIGURE 6.1 The Dual-process Account of Self-control Implied by the Strength Model.

Note: Two processes, one top-down and controlled, and the other bottom-up and automatic, compete with each other to determine self-control success or failure.

paradigm comes about have been lacking, with many questions remaining (Inzlicht & Berkman, 2015). It is thus possible for self-control to wane after initial exertion, but for reasons that have little to do with depleted resources (Inzlicht, Schmeichel, & Macrae, 2014).

Before we delve more directly into some of the literature that challenges the resource account, it seems pertinent at this point to make clear some of the assumptions that underlie ego depletion and the use of the sequential task paradigm. Much of the ego depletion literature either implicitly or explicitly (e.g., Schmeichel, Harmon-Jones, C., & Harmon-Jones, E., 2010) endorses the notion that self-control behavior is the product of two competing forces: an impulsive force pushing against self-control, and a countervailing controlling force pushing toward it (see Figure 6.1). The crux of the depletion phenomenon is captured nicely in this "dual-process" model under the assumption that the impulsive force is constant (i.e., an automatic, "System 1" process), whereas the controlling force is finite or depletable (i.e., a controlled, "System 2" process; Hofmann, Friese, & Strack, 2009). Thus, in a given situation, while the controlling force might win out for some time, it will inevitably become depleted, at which point the automatic force—which is always present—takes over. This model has been adopted in social and cognitive neuroscience studies of depletion (Heatherton & Wagner, 2011), and in large part explains the design of those studies. Notably, these studies typically manipulate the controlled process (e.g., emotional suppression, attention control), and then examine its effect on some measure that taps an automatic or impulsive process (Stroop errors, emotional reactivity, food consumption, etc.).

In what ways are these studies problematic, or more particularly, are the explanations of their results as an example of depleted resources problematic? In the following section, we summarize these issues before turning to the neuroscience of self-control for alternative explanations of the refractory period.

Problems with the Resource Account

What Is the Resource?

The first problem with the resource account is the inability to specify a *plausible* resource that fuels the will. Instead of being measured, the presence of a depleted resource has mostly been inferred based on performance on the second of two self-control tasks in the sequential task paradigm. However, self-control can have a refractory period without it being based on the depletion of limited energy stores (Inzlicht & Schmeichel, 2012). So what is the resource?

Most studies never observe resource depletion. The one exception comes from studies that have measured glucose (Gailliot et al., 2007), which is a carbohydrate that circulates in the bloodstream and supplies energy for diverse activities of the body and brain. By showing that initial self-control exertion leads to a measurable drop in circulating blood glucose, which then mediated the reductions in self-control attributed to ego depletion, these studies vindicated the resource model. The physical resource at the core of the resource model, then, is glucose. But is it really?

The glucose findings have proven to be very controversial and have been challenged on multiple grounds. First, the idea that self-control can consume inordinate amounts of brain glucose is biologically implausible (Kurzban, 2010). Studies using positron emission tomography (PET), which directly measures localized changes in brain glucose metabolism, suggest that specific mental activities cause a local increase in glucose utilization of no more than 1% above resting levels (Raichle & Mintun, 2006). Mental effort, in other words, consumes very little brain glucose, and the little that it does use is readily circulating in the brain (Hockey, 2013). Second, the finding that self-control actually depletes measurable levels of blood glucose has been difficult to replicate. Molden and colleagues (2012), for example, repeatedly assessed carbohydrate metabolization with highly precise measurements under carefully standardized conditions and failed to find that exerting self-control reduced levels of blood glucose. Third, the original studies used to support the glucose account (Gailliot et al., 2007) have been criticized on statistical grounds, with some claiming that the studies suffered from excessively low statistical power, and were thus "incredible" or too good to be true (Schimmack, 2012), while others reanalyzed the original data with claims of discrepant results (Kurzban, 2010).

In short, if exerting self-control does not reliably reduce blood glucose levels, then the idea that glucose is the physical manifestation of the metaphorical resource is in doubt. Self-control may nevertheless operate based on some limited inner resource, but the resource must be something other than glucose.

Incompatible Findings

While the identity of the fuel-like resource remains in doubt, findings have accumulated that are incompatible with a resource account, thus straining the necessity of a resource concept to explain self-control's refractory period (Inzlicht, Schmeichel, et al., 2014; Navon, 1984). The ever-growing numbers of incompatible findings are of two sorts. The first typically indicates that depletion effects are moderated by adding extra inputs or reward to the self-control task, while the second indicates that depletion is moderated by subjective perceptions, expectations, and construals.

First, rewarding self-control undoes the depletion effect; it cancels its apparent refractory period. This first was discussed by Muraven and Slessareva (2003), who found that participants could maintain high levels of control over time if they were offered cash or interpersonal incentive to do so. Similarly, incentivizing control by re-framing temptations as tests of willpower cancels depletion (Magen & Gross, 2007). Rewarding effort on the Time 2 task, then, undoes the reductions in control due to previous task exertion. In addition to adding value to the Time 2 task, value can be enhanced by adding other inputs or rewards to the intervening period between the two tasks; and when this is done, depletion effects become knocked out. Thus smoking cigarettes (Heckman, Ditre, & Brandon, 2012), watching a favorite television program (Derrick, 2012), experiencing a positive change in mood (Tice, Baumeister, Shmueli, & Muraven, 2007), affirming some core value (Schmeichel & Vohs, 2009), gargling with sugar (Hagger & Chatzisarantis, 2013; Molden et al., 2012), meditating (Friese, Messner, & Schaffner, 2012), or even praying (Friese & Wänke, 2014) similarly defend against the reductions in self-control observed in the sequential task paradigm.

Studies of this sort are very hard to reconcile with a resource account. If self-control truly relies on some limited, slowly replenishing resource that becomes depleted after use, it is difficult to understand how simple incentives can reverse this depletion. It appears from these studies as if self-control's refractory period has more to do with motivation and value, rather than capacity. Although some have claimed that motivation only matters when people are "partially depleted," and that "true depletion" cannot be counteracted (Vohs, Baumeister, & Schmeichel, 2012), this is incompatible with field and laboratory studies showing that simple incentives can counteract the effects of fatigue from very long bouts of cognitive labor (Boksem, Meijman, & Lorist, 2005; Hockey & Earle, 2006). Thus, anything that adds value—be that the perception of choice, a cigarette, or positive feelings—acts like an input that determines whether a person decides to apply effortful control or not. Self-control's refractory period, then, may be based on changes in people's willingness to engage control, rather than changes in some physical capacity.

Second, changing perceptions and construals can also counteract depletion. Thus, when people perceive themselves as being depleted, despite not having engaged in previous cognitive work, they exhibit poor self-control; conversely, when people perceive themselves as having lots of energy and stamina, in contrast, they show fully intact self-control (Clarkson, Hirt, Jia, & Alexander, 2010). Likewise, perceptions of sleep quality predict cognitive performance, while actual sleep quality does not (Draganich & Erdal, 2014). Perception of depletion, then, predicts control outcomes. Similarly, lay theories about how self-control works and whether it does or does not have a refractory period trump "actual" depletion (Job, Dweck, & Walton, 2010). When people believe that self-control wanes over time, they show typical depletion effects; however, when they believe that self-control is renewable, they show no noticeable drops in self-control over time. Finally, new work suggests that the construal of effort itself can determine whether it leads to depletion. When people construe an effortful activity as work, they tend to show subsequent failures in control; when they construe the same task as fun and enjoyable, they tend not to show these deficits (Werle, Wansink, & Payne, 2014).

As with the studies of motivation, it is difficult to reconcile these studies with the resource model. If self-control is based on some physical resource that is depletable, it is not clear how subjective perceptions, expectations, and construals should make a difference. Self-control's refractory period, then, may be due to people consciously or unconsciously limiting themselves, believing that they cannot go on when they can (Hockey, 2013), or conserving energy for an upcoming challenge (Muraven, Shmueli, & Burkley, 2006; Tyler & Burns, 2009). It may have more to do with their expectations about how feelings of fatigue predict performance, and less about fatigue signaling some biologically mediated incapacity.

Taken together, it is clear that the resource model as originally conceived is untenable. No reliable and plausible resource has ever been found, and more and more studies implicate motivation and expectations in driving the ego depletion effect. Despite this, this ego depletion effect is real and replicable (Hagger et al., 2010; however, see Carter & McCullough, 2013), and thus there is a real need for a plausible, mechanistic, and neuroscientifically informed model to help us understand it. And so we now briefly explore some of the neuroscience of self-control—and the neuroscience of depletion—to find clues about the true mechanisms underlying the depletion effect.

The Neuroscience of Self-control

Quite a bit of knowledge has been created by studies from cognitive neuroscience focusing on what might be considered sub-components of self-control such as response inhibition, attentional control, and error monitoring (see Schmeichel, 2007, for a discussion of the relations among several of these). A full review of these studies is beyond the scope of this chapter and, more importantly, because the purpose of those studies is to identify which brain regions are involved in self-control, they do not necessarily advance social psychological theories on what self-control is, why it has an apparent refractory period, or how to improve it (we will return to that point below). For our purposes here, it is sufficient to say that a network of brain structures broadly implicated in "top-down" cognitive control, including the dorsolateral and ventrolateral prefrontal cortices (DLPFC, VLPFC), the dorsal anterior cingulate cortex (dACC), and the lateral parietal cortex are reliably found to be active during tasks related to self-control (Cohen, Berkman, & Lieberman, 2013; Wager et al., 2005). Since establishing the basic network, researchers in cognitive neuroscience have focused their efforts on pinpointing the specific mental processes linked with the various anatomical regions involved in top-down control. Though this work is still ongoing, there is some consensus that the DLPFC is involved in planning and rule maintenance (Miller & Cohen, 2001), the VLPFC is involved in inhibitory control and set shifting (Aron, Robbins, & Poldrack, 2004, 2014; Monsell, 2003), the dACC in conflict/error monitoring (Botvinick, Cohen, & Carter, 2004), and lateral parietal regions are involved in working memory maintenance and updating (Vilberg & Rugg, 2008). From a social psychological perspective, each of these processes might be considered necessary, but not sufficient, for self-control.

Moving beyond broad cognitive studies on the details of self-control, a handful of recent neuroimaging studies have specifically targeted self-control depletion. To some extent, it is surprising that this research did not emerge until now, given the relatively long time that cognitive neuroscientists have studied constructs related to self-control. One reason for this may be that the cognitive sub-components of self-control do not appear to fatigue with use in the way they are studied in the cognitive neurosciences. For example, working memory or error monitoring tasks can last 30–40 minutes—longer than the typical ego depletion study—without an apparent drop-off in performance (though we note that one study found that 2 hours of continuous performance did eventually decrease error monitoring performance; Boksem et al., 2005). Nonetheless, there is very little evidence of fatigue effects in the cognitive neuroscience literature, suggesting that whatever the cause of the depletion is, it is probably not a predetermined limit on core cognitive processes *per se*.

Researchers have now conducted studies of ego depletion using the two predominant human neuroimaging modalities: electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). Electroencephalography has been deployed to measure event-related potentials (ERPs) associated with self-control and/or self-control failure, and fMRI has been used to indirectly measure neuronal activity (in the form of the blood-oxygenation-level-dependent, or BOLD, signal) before and after depletion.

Two EEG studies have now used a key neural correlate of error monitoring, the so-called error-related negativity (ERN), as an index of self-control ability following a self-control effort (emotional suppression: Inzlicht & Gutsell, 2007; Wang & Yang, 2014). The ERN is an evoked brain potential time-locked to when people make errors (Gehring, Goss, Coles, Meyer, & Donchin, 1993), and it is thought to reflect activity of a conflict-monitoring system (Botvinick et al., 2004; Holroyd & Coles, 2002) that is generated by the dACC (Dehaene, Posner, & Tucker, 1994). In both studies, participants who suppressed their emotions in an initial phase subsequently performed worse on a Stroop task and had diminished ERNs on error trials, compared with control participants who did not suppress their emotions. The reduced ERN mediated the decrement in performance (Inzlicht & Gutsell, 2007), and this effect was specific to emotional suppression and not to emotional reappraisal (Wang & Yang, 2014). These two studies are consistent with the general prediction of the resource model that some specific top-down cognitive resource, perhaps error monitoring, becomes fatigued with use, which in turn hampers subsequent self-control efforts.

Three fMRI studies have attempted to map out the neural effects of ego depletion using similar paradigms to the EEG studies described above. In the most similar study, Friese and colleagues (Friese, Binder, Luechinger, Boesiger, & Rasch, 2013) assessed neural activity during both an initial emotion suppression (or control) task and then a subsequent Stroop task. Relative to the control group, DLPFC activation in the suppression group was greater during the initial task and then reduced on incongruent trials during the Stroop task. However, this pattern emerged *only* for the right DLPFC, and not for the left DLPFC, nor the dACC, even though all three regions were co-active during both tasks and thus presumably involved in self-control in some way. Furthermore, the key relationship between DLPFC activation during the Time 1 emotion suppression task and the Time 2 Stroop task (within the suppression group) was not reported. The presence of this relationship would suggest that the degree of effort in the Time 1 task was directly related to the decrement in performance on the Time 2 task, which follows from the prediction that both tasks draw upon the same (depletable) resource. Without evidence of a shared process, the possibility remains that the Time 2 decrements are caused by the Time 1 exertion via a separate process (e.g., shifting priorities and/or motivation).

The other two fMRI studies leveraged the ability of fMRI data to interrogate connectivity between various brain regions to address the underlying neurocognitive process(es) of depletion in a more nuanced way than was previously possible. Both studies examined the effect of ego depletion—this time generated by exerting effort to inhibit attention to distracting words overlaid on a video—on behavioral and neural responses to negative emotional scenes (Wagner &

Heatherton, 2013) and to delicious but unhealthy food images in a dieting sample (Wagner, Altman, Boswell, Kelley, & Heatherton, 2013). Neural activity was measured in both studies during cue exposure (to negative scenes or food images) before and after the depletion phase, and both studies found *increases* during exposure in emotional reactivity regions (amygdala and orbitofrontal cortex) from pre- to post-depletion in the depleted group; conversely, there was either a decrease or no change in the control group. In other words, depletion caused people to be more reactive to some affective stimuli than they otherwise would have been. Intriguingly, there were no differences between the groups in the activity of any top-down control regions, but both studies reported diminished *functional connectivity* between the DLPFC and the respective reactivity regions; in controls, there was a robust inverse relationship between the DLPFC and the amygdala/orbitofrontal cortex, but that inverse relationship was eliminated in the depletion group. According to the fMRI studies, then, the apparent process is not that depletion entirely knocks out top-down control *per se*, but rather that depletion uncouples top-down control from emotional reactivity when it otherwise would be engaged. Control processes, in other words, become unmoored from reactivity, when they normally operate in a synchronized, albeit reciprocal, fashion.

It is important to emphasize at this point that these studies highlight some of the limitations of the "dual-process" aspect of much of the ego depletion literature. First, in the fMRI studies that examined connectivity (Wagner et al., 2013; Wagner & Heatherton, 2013), self-control performance decrements following depletion were systematically linked to the degree of coupling between the controlling process and the impulsive process. This pattern suggests that the two processes do not independently compete for control of behavior, but instead they are in some way interdependent. This is important because there is evidence that the degree of the coupling is context-dependent (e.g., that it changes as a function of the stimulus class; e.g., Wagner & Heatherton, 2013), indicating that additional processes beyond the basic two might modulate the competition between them and its outcome. Second, and supporting the first idea, even after 2 hours of depleting mental effort, participants' ability to engage in self-control could be restored (or "repleted") by increasing their motivation to perform well on the task with a monetary incentive (Boksem et al., 2005). On the surface, this finding suggests that motivation must be accounted for somehow in depletion models. As we will see, this is a challenge for the dual-process models that underlie depletion accounts, because motivation does not cleanly fit into either of the dual processes since it can be driven both by automatic (e.g., primary reward) and controlled (e.g., goal setting) processes. On a deeper level, this finding challenges the basic assumption that there is a hard limit on certain (i.e., controlled) processes, but not on others (i.e., impulsive). At the neural level, signals such as the ERN can be restored, even after 2 hours of effort, with minimal incentives.

The Refractory Period as Changes in Motivation

As we have just seen, the still emerging literature on the neuroscience of self-control depletion offers clues to the processes that underlie self-control's refractory period. Some studies indicate that depletion leads to decreases in brain activity in regions related to cognitive control (Friese et al., 2013; Inzlicht & Gutsell, 2007; Wang & Yang, 2014). Studies of this sort are consistent with the resource model view of depletion as an inability to regulate—depletion here could be interpreted as some neural deficiency whereby initial effort reduces neural resources available for the top-down regulation of prepotent responses. Other studies, however, fail to show deficiencies in brain regions related to control, and instead show increased activity in brain regions related to motivational salience and reward value (Wagner et al., 2013; Wagner & Heatherton, 2013). Studies of this latter type add nuance to the depletion literature and suggest that self-control's refractory period may be less a product of an inability to control oneself and more a product of people's desires changing and strengthening over time.

Alternative Account 1: The Shifting Priorities Model

Also called the process model of depletion (Inzlicht & Schmeichel, 2012; Inzlicht, Schmeichel, et al., 2014), the shifting priorities model integrates research from multiple areas, including the opportunity cost model of performance (Kurzban et al., 2013), work on the aversiveness of control (Botvinick, 2007; Kool, McGuire, Rosen, & Botvinick, 2010), and the psychology of fatigue (Hockey, 2013).

The model first attempts to address *why* self-control wanes over time, suggesting that this temporal dynamic was evolutionarily selected to solve a recurrent problem in human life (Tooby & Cosmides, 1992): the problem of balancing the needs for exploitation versus exploration, whereby the value of exploiting established sources of reward is pitted against the utility of exploring the environment for other opportunities (Cohen, McClure, & Yu, 2007; Tooby & Cosmides, 2005). Balancing this trade-off involves regulating the extent to which the control system favors task engagement (exploitation) versus task disengagement (exploration). Knowing when to persevere and when to change course is a balancing act—if the appropriate balance is not maintained, people may expend too much effort for too little reward or prematurely give up on an endeavor before some large pay-off. The point here is that natural selection would have favored adaptations that minimize opportunity costs caused by a poor decision about whether to engage or to disengage from a task (Kurzban et al., 2013). One such adaptation is making effortful control aversive, as having inherent disutility (Kool et al., 2010).

Because effortful control is aversive, not only do people tend to avoid it, but their desire to avoid it increases the more time they spend engaged in effortful control (Kool & Botvinick, 2014). In other words, the inherent disutility of cognitive work accumulates the more one has engaged in work already. This is another way of saying that people increasingly prefer rest and leisure after engaging in cognitive work and effort.

From this perspective, self-control's refractory period may be the motivated switching of task priorities, wherein all forms of mental effort become increasingly aversive, making mental leisure increasingly attractive. What this means is that depletion may not be about some finite resource being exhausted, but about people's preferences and priorities changing. Specifically, initial bouts of effort may lead people to subsequently prefer engaging in "want-to" goals as opposed to "have-to" goals (Inzlicht, Schmeichel, et al., 2014). That is, people may experience a shift in motivation away from "have-to" or "ought-to" goals, which are carried out through a sense of obligation and duty, and instead come to prefer "want-to" goals, which are fun, personally enjoyable, and meaningful (Deci & Ryan, 2002). Although this motivational shift was originally conceived as primarily influencing subsequent attention (Inzlicht & Schmeichel, 2012), or subsequent attention and emotion (Inzlicht, Schmeichel, et al., 2014), it probably affects all information-processing modalities (e.g., perception, memory, etc.) given motivation's far reach. Thus, depletion might not only affect what people pay attention to in their environment, but also how they perceive and remember it.

Without some reward to offset the increasing aversiveness of work, people will prefer to engage in activities they find more immediately pleasurable (Inzlicht, Schmeichel, et al., 2014). Thus, self-control can be seen as the product of multiple inputs that either add or subtract value from the eventual decision about whether to engage cognitive effort. While effort may itself have inherent disutility, this can be countered by the many additional sources of value—including being self-affirmed (Schmeichel & Vohs, 2009), gargling with sugar (Molden et al., 2012), or getting the opportunity to pray (Friese & Wänke, 2014)—that may lead someone to decide to forego immediate gratification in order to engage control. This disutility can also be countered by framing effort as a means toward some inherently fun and enjoyable end, thereby changing the value of effort itself, as when walking is framed as sight-seeing instead of exercise (Werle et al., 2014). In this light, expectations about how self-control works (Job et al., 2010) and perceptions of fatigue and vitality (Clarkson et al., 2010; Draganich & Erdal, 2014) are additional inputs that add or subtract value from the decision about whether or not to apply effort. Seeing self-control as the product of multiple inputs that influence the decision about whether to exert effort is consistent with emerging views from cognitive neuroscience.

Alternative Account 2: The Valuation Model

A second model, which complements the first, is derived from neuroeconomics literature on decision-making and the valuation of stimuli. In this model, self-control is driven by *subjective value*, such that the perceived value (or utility) of the response options are the principal determinant of any given self-control decision. Subjective value is a function of input from a large range of sources (e.g., perceived difficulty, monetary value, social value, self-relevance, etc.) that are integrated into a common value signal which then presumably drives self-control (or impulsive) actions. Critically, these sources (a) can fluctuate over time as situations evolve; and (b) contain a blend of automatic and controlled processes that do not necessarily oppose one another. Thus, self-control can be viewed as a "single process," namely as the integration of an arbitrary number of value signals to a unitary value calculation. This idea nicely accounts for both traditional ego depletion effects and the more recent data that challenge the original dual-process account, and is supported by emerging evidence from neuroscience. Below, we review recent evidence from social neuroscience and social psychology for this view.

The strongest neuroscientific evidence for this valuation model of self-control comes from the neuroeconomics literature. This research explicitly models decision-making as a process of value comparison among various response options, wherein the option with the highest subjective value is chosen (Rangel, Camerer, & Montague, 2008). Studies adopting this approach consistently find that activation in one region in particular—the ventromedial prefrontal cortex (vmPFC)—is involved in value computations of both appetitive and aversive stimuli (Tom, Fox, Trepel, & Poldrack, 2007). In their program of research, Rangel and colleagues have found that the vmPFC integrates information across a range of properties about a stimulus to produce a final value signal that includes stimulus properties, active goals, costs, and other types of choice-relevant information (Rangel & Hare, 2010). For example, in one study (Hare, Camerer, & Rangel, 2009), participants separately rated the tastiness and healthiness of a series of food stimuli, and then made choices about whether or not to eat each food. Activity in the vmPFC predicted stimulus value (i.e., choice) regardless of whether the choice was driven by health or taste concerns. In another study (Hare, Camerer, Knoepfle, O'Doherty, & Rangel, 2010), activity in the vmPFC at the time of choice correlated with previous ratings of the value of charitable organizations. That study also found that the vmPFC received inputs from brain regions associated with social cognition, which is presumably involved in placing a subjective value on charitable giving options. Thus, the vmPFC appears to be a point of convergence for value-related information during choices that may be relevant to self-control (e.g., tasty versus healthy food choices).

In further support of the notion that the vmPFC is a global valuation region, the vmPFC appears to calculate the subjective value of a range of stimuli. For example, vmPFC activity accurately predicts choices regardless of whether the stimuli in question are food or money (Levy & Glimcher, 2011). A related study found that activity in vmPFC scales with the subjective value of a monetary gain for oneself and another person (Zaki, López, & Mitchell, 2014). First, in a series of binary forced-choice options, participants chose between gains for themselves or gains for another person. Based on these responses, the experimenters computed a scaling factor to describe the relative value of gains for oneself and for another (e.g., If I'm equally likely to keep $8 for myself as I am to give $4 to you, then my scaling factor between self and other is 2.). Then, in a separate set of trials, gains were separately offered to the self or the other. In these trials, vmPFC activity linearly scaled with the *subjective* value of the gains (e.g., It was equal for an $8 gain for you and a $4 gain for myself.). Not only does the vmPFC reflect value, then, but it also scales value across disparate outcome types in a common valuation system to facilitate choice among them (Levy & Glimcher, 2011), making this region a likely candidate to be the final locus of value inputs from a range of qualitatively different processes.

From this perspective, self-control is less a battle between "hot" impulses and "cold" control (Metcalfe & Mischel, 1999) than it is an integration of value inputs from an arbitrary number of sources including primary rewards, salient goals, social value, effort costs, etc. (see Figure 6.2). Critically, under the value calculation model, success in self-control can be increased by amplifying the value of the self-control action (i.e., boosting the *goal-relevant* value), attenuating

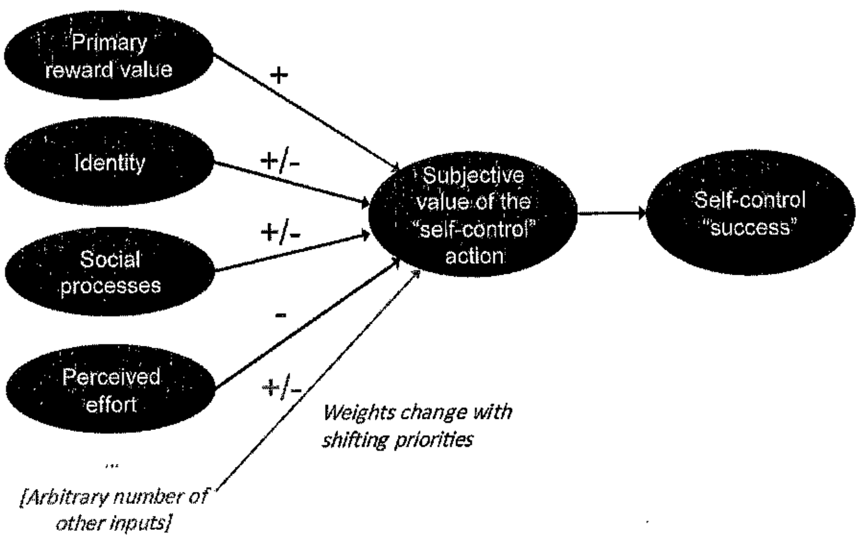

FIGURE 6.2 The Valuation Model of Self-regulation.

Note: An arbitrary number of input processes such as primary/secondary rewards, identity, social context, and effort costs (left) contribute to the subjective value (middle) of the response options (e.g., the "regulated" and "impulsive" actions). The option with the highest subjective value is enacted (right).

the value of the impulsive action, or some combination of the two. A dramatic example of the success of this approach comes from research on contingency management treatment for substance use disorders (Bigelow & Silverman, 1999), in which the value of drug abstinence is increased with monetary incentives. A meta-analysis found this approach to have an effect size d = 0.42 on treatment for alcohol, tobacco, and illicit drugs, which was larger than therapy (d = 0.25) and outpatient treatment (d = 0.37), and comparable to methadone treatment for opiate use (Prendergast, Podus, Finney, Greenwell, & Roll, 2006). Another line of work relating value to self-regulation has found that monetary incentives increase persistence at exercise (Cabanac, 1986) and endurance on a cold-pressor task (Baker & Kirsch, 1991). A final example comes from research on the ego depletion effect itself. Rewarding participants with monetary incentives for performance (Muraven & Slessareva, 2003), or even the thought of incentives (Boucher & Kofos, 2012), mitigates or eliminates the ego depletion effect, consistent with the idea that increasing the value of self-control can improve performance in cases when it would otherwise drop off.

Other psychological processes beyond reward can also impart value to self-control. For example, identity or self-relevance has intrinsic value (Greenwald et al., 2002), so, all else being equal, decisions that are related to one's identity would be expected to have higher value—and therefore are more likely to promote self-control—than decisions that are not identity-relevant. Identity priming and other manipulations that make identity salient (e.g., self-affirmation) can thus attenuate the ego depletion effect or eliminate it altogether. Schmeichel and Vohs (2009) tested this by inserting a self-affirmation manipulation between the first and second self-control tasks of the sequential task paradigm, and found that participants who wrote about core values performed just as well, if not better, on the second of the two tasks after they were "depleted." Choice and autonomy also eliminate or reduce the ego depletion effect relative to autonomy-undermining or forced conditions (Moller, Deci, & Ryan, 2006; Muraven, Gagné, & Rosman, 2008; Sheldon & Elliot, 1998). These results are consistent with self-determination theory's (Deci & Ryan, 1985; Ryan & Deci, 2000) prediction that tasks motivated intrinsically (versus extrinsically) are viewed as more self-relevant, and are thus afforded greater effort and resources. Along these lines, one study even found that inducing self-awareness between the first and second self-control tasks eliminates the depletion effect (Alberts, Martijn, & de Vries, 2010). Finally, manipulating the salience of self-control itself increases self-control, presumably because many people value willpower as an attribute (Magen & Gross, 2007; Study 2). In that study, participants completed a self-control task twice, and in between were randomly assigned to reconstrue *the task itself* as a measure of their own "willpower" or not. Performance improved only among participants whose perceptions of the task were changed from non-diagnostic to diagnostic of willpower. All of these findings are consistent with a single-process model such that increasing the salience of identity (via self-affirmation, increasing self-awareness, or priming autonomy goals) bolsters self-control performance by reminding people of the inherent value of their identity in the relevant domain.

The link between identity and subjective value is further supported by the fact that the neural systems for the two processes are nearly identical. As noted above, the vmPFC appears to be the locus of a common value calculation; this region is also active in a range of self and identity processes. The vmPFC is active when people reflect on their own traits (Kelley et al., 2002; Pfeifer, Lieberman, & Dapretto, 2007), attitudes and preferences (Ames, Jenkins, Banaji, & Mitchell, 2008; Mitchell, Macrae, & Banaji, 2006), and ongoing emotional experience (Ochsner et al., 2004; Phan, Wager, Taylor, & Liberzon, 2002). Furthermore, activity in the medial prefrontal cortex (mPFC) during encoding of information correlates with memory recall for that information, but only when encoding used a self-referential mnemonic (Macrae, Moran, Heatherton, Banfield, & Kelley, 2004). A meta-analysis of over 200 neuroimaging studies further supports the role of the mPFC in self-related processes, particularly implicating the vmPFC in self-processing (Van Overwalle, 2009). Indeed, the high degree of overlap between self-processing and value in the vmPFC has led researchers to re-characterize its function as a hybrid between the two, to "assign significance to self-relevant experiences based on individuals' motivations (needs, goals) that are salient at a given moment" (Kim & Johnson, 2014, p. 499).

Implications of the New Models for Understanding and Improving Self-control

Integrating the two alternative accounts—the shifting priorities model and the valuation model—presents an entirely new perspective on self-control and its depletion. The fundamental cause of depletion, in this view, is that people value task performance less and value disengagement more. Indeed, why shouldn't they? Presumably, research participants enter the laboratory with some amount of motivation to engage in the experimental task. The source of this motivation might be to get course credit or money, or might be a result of a self-consistency motive (e.g., "I showed up to the experiment, so I must want to be here."). Despite being initially motivated (even somewhat), the value these participants place on later tasks in a study (after they have completed the first task) might be quite low in comparison. Valuation is an ongoing process; it changes with the situation. After an initial task, participants may feel that their obligations are fulfilled or that they are licensed to slack off more (Huberts, Evers, & De Ridder, 2012). Eventually, self-control falls off because priorities shift to more highly valued activities, such as leisure, or even effortful tasks that are more personally relevant or rewarding.

The integrated model makes a number of new predictions that will need to be tested and borne out empirically. We close by discussing its implications for self-control improvement. On the first order, the most direct way to boost self-control is to increase its value. We have alluded to several ways of doing that: through monetary incentives, through identity/self-affirmation, and even by reminding people about the value of self-control itself. If the strength of self-control is driven more by value than by a particular cognitive ability, then a new aim for the field of self-control becomes the characterization of what people value and how to push those values around.

We suggest that the study of self and identity is a rich starting point for these investigations. For example, self-determination theory (Deci & Ryan, 1985) has articulated the effects of intrinsic motivation on goal pursuit broadly, and self-control specifically. We have already discussed the idea that depletion signals an opportunity cost of effort (Kurzban et al., 2013); an intriguing possibility under our model is that self-control enacted in the service of the most highly prioritized intrinsic goals will evince little or even no depletion because there is literally nothing else with higher value. Anecdotal evidence certainly supports this idea, as suggested in the famous quote attributed to Confucius, "Find a job that you love and you will never work another day in your life." The vast majority of the ego depletion literature involves tasks that have little intrinsic value for participants. A straightforward research question is to establish whether intrinsically motivated self-control is depletable to the same degree as extrinsically motivated self-control. There is some indirect evidence that this may be the case (Moller et al., 2006), but more direct evidence is needed.

In the long term, the field may need to develop ways of turning extrinsic goals into intrinsic ones. How can or does something *become* self-relevant? How can we turn our "should" goals into "want" goals? Again, the literature from self and identity reveals some promising ideas. For example, a simple "noun–verb" manipulation has been shown to increase self-regulatory behaviors, if not self-control *per se*. In one study, phrasing questions about voting intentions in terms of identity (noun: "being a voter") instead of an action (verb: "voting") increased voting intentions and actual turnout in statewide elections (Bryan, Walton, Rogers, & Dweck, 2011). In another, participants were less likely to cheat (by claiming money they were not entitled to) if the behavior was described as an identity (noun: "being a cheater") instead of an action (verb: "cheating"; Bryan, Adams, & Monin, 2013). Both of these results are consistent with the idea that identity influences self-control, perhaps by highlighting the subjective value of desired ("voter") or undesired ("cheater") identities. The field has made tremendous progress by going down the "control" road to understanding self-control; perhaps it is time to follow studies like these down the "self" path for a while.

References

Alberts, H. J. E. M., Martijn, C., & de Vries, N. K. (2010). Fighting self-control failure: Overcoming ego depletion by increasing self-awareness. *Journal of Experimental Social Psychology, 47*(1), 58–62.

Ames, D. L., Jenkins, A. C., Banaji, M. R., & Mitchell, J. P. (2008). Taking another person's perspective increases self-referential neural processing. *Psychological Science, 19*(7), 642–644. doi:10.1111/j.1467-9280.2008.02135.x

Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences, 8*(4), 170–177.

Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2014). Inhibition and the right inferior frontal cortex: One decade on. *Trends in Cognitive Sciences, 18*, 177–185.

Baker, S. L., & Kirsch, I. (1991). Cognitive mediators of pain perception and tolerance. *Journal of Personality and Social Psychology, 61*(3), 504–510.

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology, 74*(5), 1252.

Baumeister, R. F., & Heatherton, T. F. (1996). Self-regulation failure: An overview. *Psychological Inquiry, 7*(1), 1–15.

Baumeister, R. F., Vohs, K. D., & Tice, D. M. (2007). The strength model of self-control. *Current Directions in Psychological Science, 16*, 351–355.

Berkman, E. T., & Falk, E. B. (2013). Beyond brain mapping: Using neural measures to predict real-world outcomes. *Current Directions in Psychological Science, 22*(1), 45–50.

Berkman, E. T., Falk, E. B., & Lieberman, M. D. (2011). In the trenches of real-world self-control: Neural correlates of breaking the link between craving and smoking. *Psychological Science, 22*(4), 498–506.

Bigelow, G. E., & Silverman, K. (1999). Theoretical and empirical foundations of contingency management treatments for drug abuse. In S. T. Higgins & K. Silverman (Eds.), *Motivating behavior change among illicit-drug abusers: Research on contingency management interventions* (pp. 15–31). Washington, DC: American Psychological Association.

Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research, 25*(1), 107–116.

Botvinick, M. M. (2007). Conflict monitoring and decision making: Reconciling two perspectives on anterior cingulate function. *Cognitive, Affective & Behavioral Neuroscience, 7*(4), 356–366. Retrieved from www.ncbi.nlm.nih.gov/pubmed/18189009

Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Sciences, 8*(12), 539–546.

Boucher, H. C., & Kofos, M. N. (2012). The idea of money counteracts ego depletion effects. *Journal of Experimental Social Psychology, 48*(4), 804–810.

Bryan, C. J., Adams, G. S., & Monin, B. (2013). When cheating would make you a cheater: Implicating the self prevents unethical behavior. *Journal of Experimental Psychology: General, 142*(4), 1001.

Bryan, C. J., Walton, G. M., Rogers, T., & Dweck, C. S. (2011). Motivating voter turnout by invoking the self. *Proceedings of the National Academy of Sciences, 108*(31), 12653–12656.

Cabanac, M. (1986). Keeping a cool head. *News in Physiological Science, 1*, 41–44.

Carter, E. C., & McCullough, M. E. (2013). Is ego depletion too incredible? Evidence for the overestimation of the depletion effect. *Behavioral and Brain Sciences, 36*(06), 683–684.

Clarkson, J. J., Hirt, E. R., Jia, L., & Alexander, M. B. (2010). When perception is more than reality: The effects of perceived versus actual resource depletion on self-regulatory behavior. *Journal of Personality and Social Psychology, 98*(1), 29–46.

Cohen, J. D., McClure, S. M., & Yu, A. J. (2007). Should I stay or should I go? How the human brain manages the trade-off between exploitation and exploration. *Philosophical Transactions of the Royal Society of London (Series B): Biological Sciences, 362*(1481), 933–942.

Cohen, J. R., Berkman, E. T., & Lieberman, M. D. (2013). Intentional and incidental self-control in ventrolateral PFC. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 417–440). New York: Oxford University Press.

Deci, E. L., & Ryan, R. M. (1985). The general causality orientations scale: Self-determination in personality. *Journal of Research in Personality, 19*(2), 109–134.

Deci, E. L., & Ryan, R. M. (Eds.). (2002). *Handbook of self-determination research*. New York: University of Rochester Press.

Dehaene, S., Posner, M. I., & Tucker, D. M. (1994). Localization of a neural system for error detection and compensation. *Psychological Science, 5*(5), 303–305.

Derrick, J. L. (2012). Energized by television: Familiar fictional worlds restore self-control. *Social Psychological and Personality Science, 4*(3), 299–307.

Draganich, C., & Erdal, K. (2014). Placebo sleep affects cognitive functioning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(3), 857–864.

Friese, M., Binder, J., Luechinger, R., Boesiger, P., & Rasch, B. (2013). Suppressing emotions impairs subsequent stroop performance and reduces prefrontal brain activation. *PloS One, 8*(4), e60385.

Friese, M., Messner, C., & Schaffner, Y. (2012). Mindfulness meditation counteracts self-control depletion. *Consciousness and Cognition, 21*(2), 1016–1022.

Friese, M., & Wänke, M. (2014). Personal prayer buffers self-control depletion. *Journal of Experimental Social Psychology, 51*, 56–59.

Gailliot, M. T., Baumeister, R. F., DeWall, C. N., Maner, J. K., Plant, E. A., Tice, D. M., . . . Schmeichel, B. J. (2007). Self-control relies on glucose as a limited energy source: Willpower is more than a metaphor. *Journal of Personality and Social Psychology, 92*(2), 325.

Gehring, W. J., Goss, B., Coles, M. G. H., Meyer, D. E., & Donchin, E. (1993). A neural system for error detection and compensation. *Psychological Science, 4*, 385–390.

Greenwald, A. G., Banaji, M. R., Rudman, L. A., Farnham, S. D., Nosek, B. A., & Mellott, D. S. (2002). A unified theory of implicit attitudes, stereotypes, self-esteem, and self-concept. *Psychological Review, 109*(1), 3.

Hagger, M. S., & Chatzisarantis, N. L. D. (2013). The sweet taste of success: The presence of glucose in the oral cavity moderates the depletion of self-control resources. *Personality and Social Psychology Bulletin, 39*(1), 28–42.

Hagger, M. S., Wood, C., Stiff, C., & Chatzisarantis, N. L. D. (2010). Ego depletion and the strength model of self-control: A meta-analysis. *Psychological Bulletin, 136*(4), 495–525.

Hare, T. A., Camerer, C. F., Knoepfle, D. T., O'Doherty, J. P., & Rangel, A. (2010). Value computations in ventral medial prefrontal cortex during charitable decision making incorporate input from regions involved in social cognition. *The Journal of Neuroscience, 30*(2), 583–590.

Hare, T. A., Camerer, C. F., & Rangel, A. (2009). Self-control in decision-making involves modulation of the vmPFC valuation system. *Science, 324*(5927), 646–648.

Harmon-Jones, E., & Winkielman, P. (Eds.). (2007). *Social neuroscience: Integrating biological and psychological explanations of social behavior.* New York: Guilford Press.

Heatherton, T. F., & Wagner, D. D. (2011). Cognitive neuroscience of self-regulation failure. *Trends in Cognitive Sciences, 15*(3), 132–139.

Heckman, B. W., Ditre, J. W., & Brandon, T. H. (2012). The restorative effects of smoking upon self-control resources: A negative reinforcement pathway. *Journal of Abnormal Psychology, 121*(1), 244.

Hockey, R. (2013). *The psychology of fatigue: Work, effort and control.* Cambridge, UK: Cambridge University Press.

Hockey, G. R. J., & Earle, F. (2006). Control over the scheduling of simulated office work reduces the impact of workload on mental fatigue and task performance. *Journal of Experimental Psychology: Applied, 12*(1), 50.

Hofmann, W., Friese, M., & Strack, F. (2009). Impulses and self-control from a dual-systems perspective. *Perspectives on Psychological Science, 4*, 162–176.

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences, 16*(3), 174–180.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review, 109*(4), 679–709.

Huberts, J. C. D. W., Evers, C., & De Ridder, D. T. D. (2012). License to sin: Self-licensing as a mechanism underlying hedonic consumption. *European Journal of Social Psychology, 42*, 490–496.

Inzlicht, M., Bartholow, B. D., & Hirsh, J. B. (2015). Emotional foundations of cognitive control. *Trends in Cognitive Sciences, 19*, 126–132.

Inzlicht, M., & Berkman, E. (2015). Six questions for the resource model of control (and some answers). *Social and Personality Psychology Compass, 9/10*, 511–524

Inzlicht, M., & Gutsell, J. N. (2007). Running on empty: Neural signals for self-control failure. *Psychological Science, 18*, 933–937.

Inzlicht, M., Legault, L., & Teper, R. (2014). Exploring the mechanisms of self-control improvement. *Current Directions in Psychological Science, 23*, 302–307.

Inzlicht, M., & Schmeichel, B. J. (2012). What is ego depletion? Toward a mechanistic revision of the resource model of self-control. *Perspectives on Psychological Science,* 7(5), 450–463.

Inzlicht, M., Schmeichel, B. J., & Macrae, C. N. (2014). Why self-control seems (but may not be) limited. *Trends in Cognitive Sciences, 18*(3), 127–133.

Job, V., Dweck, C. S., & Walton, G. M. (2010). Ego depletion—is it all in your head? Implicit theories about willpower affect self-regulation. *Psychological Science, 21*(11), 1686–1693.

Kang, S., Inzlicht, M., & Derks, B. (2010). Social neuroscience and public policy on intergroup relations: A Hegelian analysis. *Journal of Social Issues, 66*(3), 585–601.

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *Journal of Cognitive Neuroscience, 14*(5), 785–794.

Kim, K., & Johnson, M. (2014). Activity in ventromedial prefrontal cortex during self-related processing: Positive subjective value or personal significance? *Social Cognitive and Affective Neuroscience, 10*, 494–500. Retrieved from http://scan.oxfordjournals.org/content/early/2014/05/16/scan.nsu078.abstract

Kool, W., & Botvinick, M. (2014). A labor/leisure tradeoff in cognitive control. *Journal of Experimental Psychology. General, 143*(1), 131–141.

Kool, W., McGuire, J. T., Rosen, Z. B., & Botvinick, M. M. (2010). Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology. General, 139*(4), 665–682.

Kurzban, R. (2010). Does the brain consume additional glucose during self-control tasks? *Evolutionary Psychology: An International Journal of Evolutionary Approaches to Psychology and Behavior, 8*(2), 244–259.

Kurzban, R., Duckworth, A., Kable, J. W., & Myers, J. (2013). An opportunity cost model of subjective effort and task performance. *The Behavioral and Brain Sciences, 36*(6), 661–679.

Levy, D. J., & Glimcher, P. W. (2011). Comparing apples and oranges: Using reward-specific and reward-general subjective value representation in the brain. *The Journal of Neuroscience, 31*, 14693–14707.

Macrae, C. N., Moran, J. M., Heatherton, T. F., Banfield, J. F., & Kelley, W. M. (2004). Medial prefrontal activity predicts memory for self. *Cerebral Cortex, 14*, 647–654.

Magen, E., & Gross, J. J. (2007). Harnessing the need for immediate gratification: Cognitive reconstrual modulates the reward value of temptations. *Emotion (Washington, D.C.)*, 7(2), 415–428.

Metcalfe, J., & Mischel, W. (1999). A hot/cool-system analysis of delay of gratification: Dynamics of willpower. *Psychological Review, 106*(1), 3.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24*(1), 167–202.

Mitchell, J. P., Macrae, C. N., & Banaji, M. R. (2006). Dissociable medial prefrontal contributions to judgments of similar and dissimilar others. *Neuron, 50*(4), 655–663.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49–100.

Molden, D. C., Hui, C. M., Scholer, A. A., Meier, B. P., Noreen, E. E., D'Agostino, P. R., & Martin, V. (2012). Motivational versus metabolic effects of carbohydrates on self-control. *Psychological Science, 23*(10), 1137–1144.

Moller, A. C., Deci, E. L., & Ryan, R. M. (2006). Choice and ego-depletion: The moderating role of autonomy. *Personality and Social Psychology Bulletin, 32*(8), 1024–1036.

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, 7(3), 134–140.

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle?, *Psychological Bulletin, 126*(2), 247–259.

Muraven, M., Gagné, M., & Rosman, H. (2008). Helpful self-control: Autonomy support, vitality, and depletion. *Journal of Experimental Social Psychology, 44*(3), 573–585.

Muraven, M., Shmueli, D., & Burkley, E. (2006). Conserving self-control strength. *Journal of Personality and Social Psychology, 91*(3), 524–537. doi:10.1037/0022-3514.91.3.524

Muraven, M., & Slessareva, E. (2003). Mechanisms of self-control failure: Motivation and limited resources. *Personality and Social Psychology Bulletin, 29*(7), 894–906.

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as limited resource: Self-regulatory depletion patterns. *Journal of Personality and Social Psychology, 74*, 774–789.

Navon, D. (1984). Resources—A theoretical soup stone? *Psychological Review, 91*(2), 216.

Ochsner, K., Knierim, K., Ludlow, D., Hanelin, J., Ramachandran, T., Glover, G., & Mackey, S. (2004). Reflecting upon feelings: An fMRI study of neural systems supporting the attribution of emotion to self and other. *Journal of Cognitive Neuroscience, 16*(10), 1746–1772.

Ochsner, K. N., & Lieberman, M. D. (2001). The emergence of social cognitive neuroscience. *American Psychologist, 56*(9), 717.

Pfeifer, J., Lieberman, M., & Dapretto, M. (2007). "I know you are but what am I?!": Neural bases of self- and social knowledge retrieval in children and adults. *Journal of Cognitive Neuroscience, 19*(8), 1323–1337.

Phan, K. L., Wager, T., Taylor, S. F., & Liberzon, I. (2002). Functional neuroanatomy of emotion: A meta-analysis of emotion activation studies in PET and fMRI. *NeuroImage, 16*(2), 331–348.

Prendergast, M., Podus, D., Finney, J., Greenwell, L., & Roll, J. (2006). Contingency management for treatment of substance use disorders: A meta-analysis. *Addiction, 101*(11), 1546–1560.

Raichle, M. E., & Mintun, M. A. (2006). Brain work and brain imaging. *Annual Review of Neuroscience, 29*, 449–476.

Rangel, A., Camerer, C., & Montague, P. R. (2008). A framework for studying the neurobiology of value-based decision making. *Nature Reviews Neuroscience, 9*(7), 545–556.

Rangel, A., & Hare, T. (2010). Neural computations associated with goal-directed choice. *Current Opinion in Neurobiology, 20*(2), 262–270.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the development of intrinsic motivation, social development, and well-being. *The American Psychologist, 55*, 68–78.

Saunders, B., Milyavskaya, M., & Inzlicht, M. (2015). What does cognitive control feel like? Effective and ineffective cognitive control is associated with divergent phenomenology. *Psychophysiology, 52*, 1205–1217. doi:10.1111/psyp.12454

Schimmack, U. (2012). The ironic effect of significant results on the credibility of multiple-study articles. *Psychological Methods, 17*(4), 551.

Schmeichel, B. J. (2007). Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General, 136*(2), 241.

Schmeichel, B. J., Harmon-Jones, C., & Harmon-Jones, E. (2010). Exercising self-control increases approach motivation. *Journal of Personality and Social Psychology, 99*(1), 162–173.

Schmeichel, B. J., & Vohs, K. (2009). Self-affirmation and self-control: Affirming core values counteracts ego depletion. *Journal of Personality and Social Psychology, 96*(4), 770.

Sheldon, K. M., & Elliot, A. J. (1998). Not all personal goals are personal: Comparing autonomous and controlled reasons for goals as predictors of effort and attainment. *Personality and Social Psychology, 24*(5), 546.

Tice, D. M., Baumeister, R. F., Shmueli, D., & Muraven, M. (2007). Restoring the self: Positive affect helps improve self-regulation following ego depletion. *Journal of Experimental Social Psychology, 43*(3), 379–384.

Tom, S. M., Fox, C. R., Trepel, C., & Poldrack, R. A. (2007). The neural basis of loss aversion in decision-making under risk. *Science, 315*(5811), 515–518.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. Barkow, L. Cosmides & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 19–136). New York: Oxford University Press.

Tooby, J. L., & Cosmides, L. (2005). Conceptual foundations of evolutionary psychology. In D. Buss (Ed.), *The handbook of evolutionary psychology* (pp. 5–67). New York: John Wiley & Sons.

Tyler, J. M., & Burns, K. C. (2009). Triggering conservation of the self's regulatory resources. *Basic and Applied Social Psychology, 31*(3), 255–266.

Van Overwalle, F. (2009). Social cognition and the brain: A meta-analysis. *Human Brain Mapping, 30*(3), 829–858.

Vilberg, K. L., & Rugg, M. D. (2008). Memory retrieval and the parietal cortex: A review of evidence from a dual-process perspective. *Neuropsychologia, 46*(7), 1787–1799.

Vohs, K. D., Baumeister, R. F., & Schmeichel, B. J. (2012). Motivation, personal beliefs, and limited resources all contribute to self-control. *Journal of Experimental Social Psychology, 48*(4), 943–947.

Vohs, K. D., & Heatherton, T. F. (2000). Self-regulatory failure: A resource-depletion approach. *Psychological Science, 11*(3), 249–254.

Wager, T. D., Sylvester, C.-Y. C., Lacey, S. C., Nee, D. E., Franklin, M., & Jonides, J. (2005). Common and unique components of response inhibition revealed by fMRI. *NeuroImage, 27*(2), 323–340. doi: 10.1016/j.neuroimage.2005.01.054

Wagner, D. D., Altman, M., Boswell, R. G., Kelley, W. M., & Heatherton, T. F. (2013). Self-regulatory depletion enhances neural responses to rewards and impairs top-down control. *Psychological Science, 24*, 2262–2271.

Wagner, D. D., & Heatherton, T. F. (2013). Self-regulatory depletion increases emotional reactivity in the amygdala. *Social Cognitive and Affective Neuroscience, 8*(4), 410–417. doi:10.1093/scan/nss082

Wang, Y., & Yang, L. (2014). Suppression (but not reappraisal) impairs subsequent error detection: An ERP study of emotion regulation's resource-depleting effect. *PLoS One, 9*(4), e96339.

Werle, C. O. C., Wansink, B., & Payne, C. R. (2014). Is it fun or exercise? The framing of physical activity biases subsequent snacking. *Marketing Letters, 26*, 691–702. doi:10.1007/s11002-014-9301-6

Zaki, J., López, G., & Mitchell, J. P. (2014). Activity in ventromedial prefrontal cortex covaries with revealed social preferences: Evidence for person-invariant value. *Social Cognitive and Affective Neuroscience, 9*, 464–469.