CHAPTER

15

Cognitive Control Processes Underlying Individual Differences in Self-Control

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The strength model of self-control (Baumeister, Vohs, & Tice, 2007) proposes that individual differences in general self-control strength can explain why some people excel or struggle in multiple domains of life. Consider Alvin Wong, who was identified in a 2011 Gallup poll as one of the happiest people in the United States (Rampell, 2011). At age 69, Wong is extremely healthy, married, and has children. As a devout Jew, he maintains a strict kosher diet. He owns his own health-care business and makes $120,000 a year. In terms of emotional well-being, physical health, interpersonal relations, and financial success, Wong is thriving.

Now compare Wong to Chris Farley, the American comedian who died of a drug overdose at age 33 (Chris Farley's Death, 1998). Beyond his addiction, Farley's poor diet led to obesity and advanced heart disease. He never married or had children. Although Farley had friends, many of them publically expressed concerns about his lifestyle and well-being. Just as Wong thrived in many areas of life, Farley struggled.

One of the great accomplishments of the strength model (Baumeister et al., 2007) is that it pointed to individual differences in self-control as a parsimonious explanation for functioning across different domains. While fully acknowledging this accomplishment, one major emphasis of this chapter is that individual differences in self-control are not entirely unitary across domains. Returning to our example, one must acknowledge Chris Farley was enormously successful in his career. It is difficult to imagine how this could have happened without him refining his talents

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meticulously, persisting in the face of obstacles, overcoming fatigue to memorize his lines, etc. In short, it appears that Farley could, and did, exert a great deal of self-control in career-related efforts. How can we explain this sort of domain specificity? This chapter seeks to provide relevant answers.

In more particular terms, we review research by ourselves and others seeking to understand both domain-general and domain-specific individual differences in self-control. In doing so, we adopt a process-oriented perspective by focusing on the cognitive control processes underlying individual differences in self-control. As we will show, this approach gives rise to some precise, testable predictions concerning dispositional self-control.

After reviewing some definitional issues, we introduce a family of cognitive control models that are useful in thinking about how self-control is likely to operate. We then review three lines of work pertaining to error-monitoring, cognitive control performance, and self-control outcomes. Finally, we discuss how the cognitive control perspective can help to improve interventions designed to boost self-control and understand ego depletion effects.

WHAT IS SELF-CONTROL?

Before beginning, it is important to be clear about what self-control is and how it differs (or does not differ) from the related constructs of self-regulation and cognitive control. Self-regulation is involved in the pursuit of any goal (Carver & Scheier, 2012). Thus, self-regulation occurs both when we satisfy short-term impulses (eg, eating a candy bar) and when we achieve fairly difficult long-term objectives (eg, losing 10 pounds). Self-control, by contrast, is a term typically reserved for cases in which a person overcomes momentary desires in favor of a more valuable long-term goal (Chapter 5; Hofmann, Schmeichel, & Baddeley, 2012). Restraining from unhealthy food to maintain physical health is one example. Persisting at a difficult task (eg, studying) that could result in long-term benefits (eg, academic and career success) is another. As should be apparent, self-regulation and self-control are related but distinct constructs. Although our main focus is self-control, it is often not meaningful to discuss self-control without a consideration of the wider self-regulation context.

Cognitive control overlaps with self-control in that it involves overcoming immediate reactions in favor of a longer-term goal (or task) of the individual. Cognitive control, however, is defined in more process-oriented terms. Along these lines, Botvinick and Braver (2015, p. 85) defined cognitive control as: "[T]hat set of superordinate functions that encode and maintain a representation of the current task—ie, contextually relevant stimulus-response associations, action-outcome contingencies, and target states or goals—marshaling to that task subordinate functions including working, semantic, and episodic memory; perceptual attention; and action selection and inhibition." Other terms for cognitive control include executive function and effortful control, which are defined and assessed in very similar ways (Miyake & Friedman, 2012). Following these definitions, we use the term *cognitive control* to describe psychological processes, while we use the term *self-control* to describe outcomes consistent with resisting momentary temptation in favor of long-term goals (eg, healthy eating, academic success).

COGNITIVE CONTROL MODELS—A PRELIMINARY SKETCH

Cognitive control models (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Holroyd & Coles, 2002) share a great deal in common with cybernetic models of self-regulation (Carver & Scheier, 2012). As depicted in Fig. 15.1, a monitoring system determines whether there is a need for control by monitoring for discrepancies between what is desired and what is happening. If a discrepancy is detected, the operating systems seek to reduce it.

The Monitoring System

Multiple theories suggest that the *Monitoring* system is neurologically located in the anterior cingulate cortex (ACC) and monitors for diverse events which signal the need for control (Botvinick & Braver, 2015; Holroyd & Yeung, 2012). First, this system monitors for the simultaneous

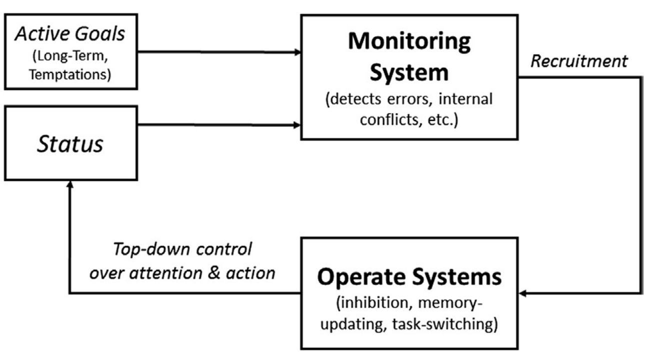

FIGURE 15.1 A cognitive control model of the processes underlying self-control.

activation of conflicting responses (Botvinick et al., 2001). This system would thus detect the conflicting responses activated by momentary temptations (eg, "Eat the chocolate!") and long-term goals (eg, "No, have a radish instead!"). In addition, this system also monitors for errors in task performance. The theory of Holroyd and Coles (2002) suggests that the basal ganglia compares expected responses and outcomes to those which actually occurred. When this result is worse than expected, this information is fed to the monitoring system in the ACC, signaling the need for control.

At a broader level, the monitoring system is sensitive to aversive events that run counter to goal attainment (Botvinick & Braver, 2015). Thus, it is a "hot" system which supports goal pursuit, rather than a "cold" information processing system. Errors and conflict are aversive events (Hajcak & Foti, 2008; Hofmann, Luhmann, Fisher, Vohs, & Baumeister, 2013), and this aversion is instrumental to subsequent control (Inzlicht & Al-Khindi, 2012). Furthermore, monitoring only occurs if the motivation for control is present. When people are unmotivated to do well on a task, error monitoring is reduced (Gehring, Goss, Coles, Meyer, & Donchin, 1993). Further, if a person knows that valued goals can be obtained, cognitive control resources can be proactively recruited ahead of time to obtain the desired goal (Jimura, Locke, & Braver, 2010).

The Operate Systems

Like the strength model (Baumeister et al., 2007), cognitive control models propose that the *Operations* underlying effective self-control depend on limited capacity resources (Botvinick et al., 2001; Holroyd & Coles, 2002). These resources are invariably identified with regions of the prefrontal cortex (ie, dorsolateral; inferior frontal junction; frontopolar). When response conflicts, errors, or other relevant signals are detected, these limited capacity resources are recruited to perform the "work" of self-control.

While the strength model contends that all acts of self-control rely on a single resource (Baumeister et al., 2007), cognitive control models propose that different cognitive control operations are supported by several distinct but overlapping neural areas. Critical to current concerns, individual differences in cognitive control performance cannot be explained by a single factor (Miyake & Friedman, 2012). Rather, three separate factors are often found. Individual differences in *inhibition* refer to the ability to override dominant responses in favor of subdominant (but contextually appropriate) response. Individual differences in *updating* refer to the ability to dynamically update the contents of memory as events change. Finally, individual differences in *task-switching* refer to the ability to flexibly switch back and forth between different tasks. Beyond this, neuroimaging studies indicate that different cognitive control tasks activate overlapping but distinct neural areas (Nee, Wager, & Jonides, 2007). Furthermore, cognitive control recruitment on one task only benefits performance on other control tasks under certain conditions (Enger, 2008).

INDIVIDUAL DIFFERENCES IN ERROR MONITORING

The cognitive control models just reviewed provide specific and testable hypotheses concerning the processes underlying individual differences in self-control. In this section, we focus on two such predictions. While the strength model has emphasized the *Operate* phase (eg, Tangney, Baumeister, & Boone, 2004), cognitive control models suggest that *Monitoring* is also critical to self-control. Furthermore, cognitive control models suggest that monitoring operations critically depend on the goals of the individual. Thus, a person can control themselves better in a particular domain if they are motivated to do so. We review research on individual differences in monitoring in light of these points. As research has mainly focused on error monitoring, we focus mainly on this aspect of monitoring as well.

Basic Research on Error Monitoring

The *error-related negativity* (ERN: Gehring et al., 1993) is an event-related potential generated by the ACC which peaks roughly 100 ms following errors on many speeded reaction time (RT) tasks (eg, the Stroop, flanker). Multiple theories (eg, Holroyd & Coles, 2002) suggest that it reflects the detection of errors by the monitoring system, triggering subsequent control. Consistent with this, posterror ACC activity is closely linked to subsequent prefrontal activity (eg, Kerns, 2006). These prefrontal regions instantiate control in part through slowed responding following errors (Gehring et al., 1993), ultimately allowing individuals to improve their subsequent performance (see Botvinick & Braver, 2015).

Error-Monitoring and Self-control Outcomes

Cognitive control models suggest that individuals higher in error monitoring should display better self-control in a variety of domains. To test this, studies have examined whether individual differences in the ERN or the posterror slowing of RTs predict self-control outcomes.

Studies have found that error monitoring is linked to greater self-control across many domains. Students who display a more robust ERN achieve a higher grade point average (Hirsch & Inzlicht, 2010). Conversely, individuals with problems related to substance abuse (Olvet & Hajcak, 2008) or obesity (Skoranski et al., 2013) display less robust ERNs. Furthermore, individuals who are prone to antisocial behavior (Wilkowski & Robinson, 2008a) and aggression (Chang, Davies, & Gavin, 2010) display less robust posterror slowing and ERNs.

Error monitoring is also linked to a variety of constructs which measure self-control more broadly construed, including externalizing (Hall, Bernat, & Patrick, 2007) and impulsivity (Potts, George, Martin, & Barratt, 2006). Moeller and Robinson (2010) also found that females display a more robust posterror slowdown in RTs than males, consistent with well-documented gender difference in self-control (eg, Else-Quest, Hyde, Goldsmith, & van Hulle, 2006).

Given the regulatory benefits of error monitoring, it is reasonable to suspect that it may lead to greater emotional well-being. This would occur because cognitive control processes are involved in emotion regulation (Ochsner & Gross, 2005) and because error monitoring is likely to facilitate goal achievement (Carver & Scheier, 2012). Consistent with this, Robinson (2007) found that individuals who show a more robust posterror slowing of RTs displayed less depression and greater happiness. Robinson, Ode, Wilkowski, and Amodio (2010) also found error monitoring was especially useful at reducing negative affect for individuals high in neuroticism. Finally, Compton et al. (2008) found that participants who displayed a more robust ERN on a Stroop task were more capable of downregulating anxious reactions to daily stressors.

Motivation and Error Monitoring

In summary, error monitoring is linked to self-control across domains. It is important to remember, however, that the monitoring system's function is to facilitate goal achievement. Accordingly, error monitoring increases when incentives are offered (Gehring et al., 1993). This suggests that when individuals are motivated to control themselves in a particular domain, they should exhibit greater error monitoring and self-control than they would otherwise.

For example, individuals who are particularly motivated to obtain rewards monitor for incentives that can be obtained through cognitive control exertion (Jimura et al., 2010). When monetary incentives were offered on working memory tasks, these individuals displayed increased activity in the prefrontal cortex.

Individual differences have also figured prominently in another line of research focused on the intrinsic motivation to control prejudice (Amodio, Devine, & Harmon-Jones, 2008). Individuals high in this motivation display more robust ERNs following errors indicative of implicit prejudice (ie, weapon misidentifications following African-American primes). This increase in the ERN was highly specific and did not generalize to other types of errors on the same or other tasks. Furthermore, it was instrumental in reducing prejudicial responding.

Finally, motivation can also help explain apparent exceptions to the general link between error-monitoring and beneficial outcomes. While there is evidence linking error monitoring to greater self-control across many domains, it is also related to greater worry and anxious apprehension (Moser, Moran, Schroder, Donnellan, & Yeung, 2013). People who habitually worry do so because they believe it serves a functional purpose (Tamir, 2005). Consistent with this, Moser et al. (2013) found that more robust ERNs were especially useful in boosting academic performance among worry-prone undergraduate students. Since these individuals believe worry is useful, they do not monitor for "errors" in mood regulation. In fact, once the risk of errors has passed, these individuals redirect their cognitive control resources to the task of worrying itself (Moser et al., 2013). Thus, both the functional and dysfunctional features of worry are consistent with a motivation-to-control analysis (Matthews & Wells, 2000).

Conscious Awareness and Monitoring

While motivation can explain domain-specific differences in monitoring, other individual differences related to conscious awareness appear to support domain-general monitoring. First, a longstanding literature has linked individual differences in *self-consciousness* to monitoring processes (Carver & Scheier, 2012). Self-consciousness is defined as the tendency to focus attention on one's self. By doing so, one's goals are maintained in an active state and goal comparisons are more likely to occur. Research has shown that people high in dispositional self-consciousness are more likely to behave in accordance with their goals (Carver & Scheier, 2012), due to increased monitoring (Scheier & Carver, 1983). Related research has shown that higher levels of self-consciousness are useful in overcoming ego depletion effects (Wan & Sternthal, 2008).

A newer literature on *mindfulness* also suggests that awareness promotes domain-general monitoring and self-control. Mindfulness is defined as a nonjudgmental awareness of one's current environment (eg, Teper, Segal, & Inzlicht, 2013). Individuals high in mindfulness accrue multiple benefits consistent with self-control. They are less anxious and depressed, experience greater satisfaction with life, report more satisfying social relationships (Brown, Ryan, & Creswell, 2007), engage in better eating habits (Jordan, Wang, Donatoni, & Meier, 2014), and are more persistent (Evans, Baer, & Segerstrom, 2009). Important for present purposes, mindfulness has also been linked to improved performance on cognitive control tasks involving inhibition (Teper et al., 2013), working memory (Jha, Krompinger, & Baime, 2007), and emotion regulation (Chambers, Gullone, & Allen, 2009). Finally, mindfulness meditation ameliorates ego depletion effects (Friese, Messner, & Schaffner, 2012).

The benefits of mindfulness appear to be due to increased monitoring and awareness of goal-relevant stimuli. For example, mindfulness has been shown to increase perceptual awareness of visual stimuli (MacLean et al., 2010) and internal physiological states (Farb, Segal, & Anderson, 2013). Furthermore, it is linked to more robust ERNs (see Teper et al., 2013).

While research on self-consciousness and mindfulness point to the importance of conscious awareness, future research should examine individual differences in *unconscious* monitoring processes. The ERN has been detected even when participants are not consciously aware of committing an error (Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001), and people can automatically compare their goals to outcomes (Moors, de Houwer, & Eelen, 2003). As cognitive control models do not require consciousness (Botvinick & Braver, 2015), unconscious monitoring processes, too, should increase self-control. However, we could locate no research directly testing this hypothesis.

Section Summary

In summary, research indicates that error monitoring is typically associated with greater self-control across a variety of domains. These domain-general outcomes are likely due to processes closely related to the nature of monitoring itself, such as mindful awareness and active goal representations. Despite these domain-general differences, individuals differ in motivation across different domains, and this creates domain-specific differences in monitoring and self-control.

INDIVIDUAL DIFFERENCES IN COGNITIVE CONTROL OPERATIONS

Cognitive control models suggest that *Monitoring* is necessary but not sufficient for self-control. In this section, we therefore turn to the *Operate* phase of cognitive control. While the strength model has emphasized the unitary nature of self-control operations (Baumeister et al., 2007; Tangney et al., 2004), cognitive control abilities are not entirely unitary (Miyake & Friedman, 2012). This section reviews these differences and their consequences.

The Unity and Diversity of Cognitive Control

According to Miyake and Friedman's (2012) influential account, individual differences in cognitive control exhibit both unity and diversity across different tasks. This model proposes a *general* factor to account for the modest positive correlations found across many cognitive control tasks. Nonetheless, the model also proposes that distinct types of cognitive control can be isolated as well.

To test this account, Miyake, Friedman, Emerson, Witzki, and Howerter (2000) gave participants a battery of nine cognitive control tasks. Three were hypothesized to represent *inhibition*, including the well-known Stroop task. Three other tasks were hypothesized to represent the ability to *update* working memory contents. For example, they administered the two-back task, which asks participants if the current stimulus matches a stimulus presented two trials prior. Finally, three other paradigms were hypothesized to represent capacities to *switch* between different tasks. In addition to these three separable factors, they hypothesized a higher-order *general* factor. Analyses using structural equation modeling provided clear support for the unity-and-diversity perspective. The hypothesized model fit the data better than models positing one unitary factor, three unrelated factors, and alternative loadings of cognitive control tasks.

More recent research indicates that the *general* factor can fully explain individual differences in *inhibition* but not *updating* or *switching*. Friedman et al. (2008) found that, after accounting for individual differences in *general* cognitive control, individual differences in the *inhibition*-specific factor were no longer significant. This suggests that psychological processes which underlie inhibition also contribute generally to updating and switching. By contrast, there appear to be unique processes involved in updating and switching.

Inhibition and Self-control Outcomes

Researchers have frequently used measures of inhibition to predict self-control outcomes (Hofmann, Schmeichel, et al., 2012). For example, the stop-signal task has frequently been used, which measures how quickly a participants can stop an initiated key press response when they are signaled to do so (Verbruggen & Logan, 2008). Individuals who perform better on inhibitory tasks are less likely to overuse drugs (eg, Houben & Wiers, 2009), overeat (Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010), commit infidelity (Karremans, Pronk, & van der Wal, 2016), or unintentionally stereotype (eg, Payne, 2005). Similarly, children who perform better on these tasks exhibit fewer problems with attention (Friedman et al., 2007), externalizing (eg, conduct disorder: Young et al., 2009), and restraint (ie, touching a forbidden toy; Friedman, Miyake, Robinson, & Hewitt, 2011).

Because individual differences in *inhibition* can be explained in terms of *general* cognitive control (Miyake & Friedman, 2012), these effects should reflect this general factor. All studies administering a battery of cognitive control tasks have found support for this idea. This has been true in studies examining the control of implicitly prejudiced errors (Ito et al., 2015), attention problems, externalizing disorder symptoms, and self-restraint (see Herd et al., 2014).

Memory Updating and Self-control Outcomes

Updating tasks also tell us something important about a person's capacity for control (Hofmann, Schmeichel, et al., 2012). People who perform better on these tasks are more capable of regulating their emotions (Schmeichel, Volokhov, & Demaree, 2008), resisting temptations (eg, Hofmann, Friese, & Roefs, 2009), controlling ruminative thought (Brewin & Smart, 2005), and lessening explicit prejudice (Ito et al., 2015).

An important question is whether the apparent benefits of *updating* are due to these abilities in particular or to the *general* cognitive control factor. The few studies which have included a larger battery of cognitive control tasks have found that updating has unique benefits. Updating predicts healthier eating (Hofmann et al., 2009), greater problem-solving ability (Friedman et al., 2008), and reduced explicit prejudice (Ito et al., 2015), even after controlling for inhibition or general cognitive control. Although more research would be useful, we tentatively conclude that updating uniquely contributes to self-control.

Switching and Self-control Outcomes

There have been comparatively fewer studies examining whether task-switching abilities predict self-control outcomes. Among the established findings is that better switching ability predicts lower implicit prejudice scores on the implicit association test (IAT; Ito et al., 2015; Klauer, Schmitz, Teige-Mocigemba, & Voss, 2010). Zero-order correlations also link greater *switching* ability to fewer attentional problems (Friedman et al., 2007) and to fewer externalizing behaviors (Young et al., 2009).

While these findings may suggest that switching is linked to improved self-control, a closer examination warns against such a conclusion. Klauer et al. (2010) points out that the IAT procedure requires people to switch between two different categorization tasks. Thus, switching may be related to implicit prejudice only because of common method variance. In support of this, improved *switching* performance is related to lower IAT scores even when self-control is quite irrelevant to the cognitive associations examined (eg, flowers vs insects) (Klauer et al., 2010). Similarly, Ito et al. (2015) found that relations between *switching* and implicit prejudice did not generalize beyond the IAT to other measures of implicit prejudice.

Of even greater interest, studies demonstrate that greater *switching* performance actually predicts lower self-control once *general* cognitive control abilities are accounted for. Such paradoxical relationships have been found for problem-solving outcomes (Friedman et al., 2008), restraint, and externalizing problems (Herd et al., 2014). This suggests that the unique variance in switching performance is actually related to worse self-control outcomes.

Processes Underlying Different Components of Cognitive Control

To summarize, research suggests that *general* and *updating*-specific components of cognitive control lead to greater self-control; while the *switching*-specific component actually leads to lower self-control once general cognitive control is accounted for. How can we explain these findings? One promising framework is the prefrontal basal ganglia working memory (PBWM) model (Hazy, Frank, & O'Reilly, 2007). This computational model is neurologically realistic and has been used to explain performance on a number of cognitive control tasks. Of further importance, the model provides insights into individual differences in cognitive control (Herd et al., 2014).

According to the PBWM model (Hazy et al., 2007), the basal ganglia is first responsible for gating information into working memory. This includes representations of goals, means of achieving these goals, and other task-relevant information. Once information is in working memory, the prefrontal cortex is responsible for maintaining it in an active state. Recurrent excitatory connections in the PFC serve this function. Finally, control itself is implemented through top-down biasing signals sent to other neural regions involved in perception and action. Through such processes, behavioral responses can be aligned with current goals.

Herd et al. (2014) recently used the PBWM to simultaneously model individual differences in Stroop and task-switching performance. The analysis suggested that the strength of the PFC's top-down influence is likely an important process underlying the *general* cognitive control factor. As the strength of top-down influence was increased in their computational model, the size of both the Stroop effect and the task-switching cost diminished, suggesting improved cognitive control on both tasks.

By contrast, the ability to actively maintain information in working memory contributed differentially to inhibitory and switching performance. As Herd et al. (2014) increased this parameter in their computational model, the Stroop incongruency effect decreased. This finding is quite sensible, as the Stroop task requires participants to continually maintain one goal (ie, name the font color) throughout the task. Interestingly, though, increasing this parameter led to *greater* task-switching costs. Although not as obvious, this finding is also quite sensible. If the cognitive representation of a task is maintained in a more active state, it will be harder for participants to switch away from it to another task.

This computational model can help explain the complex relationships between *general* cognitive control, *switching*-specific cognitive control, and self-control outcomes (Friedman et al., 2008). As strong top-down signals appear to underlie the general factor of cognitive control, they may underlie this factor's salutary effects on self-control outcomes. Once these processes are stripped away from task-switching performance, what may be left is a measure of quickly decaying goal representations. Such effervescent representations may appear to add flexibility when a person is completing a task-switching paradigm, but may lead people to forget or neglect their long-term goals in real life (see Hofmann, Schmeichel, et al., 2012, for a related analysis).

Clearly, the use of the PBWM model to understand individual differences in cognitive control is in an early stage. A more complete analysis of cognitive control tasks is needed. It would also be useful if computational work led to procedures for calculating individual difference parameters for use in empirical research. Finally, this model has not integrated monitoring processes yet. Nonetheless, we believe that the model provides a valuable tool for researchers as they begin to study the cognitive processes underlying self-control.

Section Summary

In summary, research indicates that individual differences in cognitive control are not entirely unitary. *General* cognitive control can fully account for individual differences on inhibition and partially account for updating and switching performance. Nonetheless, *updating* and *switching* clearly exist as independent factors. Furthermore, these distinctions are important. General and updating factors uniquely contribute to greater self-control, but lower residual switch costs are actually predictive of worse self-control. These insights would be missed if cognitive control was treated as a monolithic entity.

DIVERSITY ACROSS DIFFERENT DOMAINS OF SELF-CONTROL

The strength model has presented two sources of evidence to support the unitary nature of trait self-control. First, scales designed to measure trait self-control predict self-controlled behavior across a variety of domains. Second, behavior is often correlated across very different self-control domains (eg, good grades can predict prosocial behavior). We first review these two sources of evidence and then suggest that unity across different domains is far from complete. Second, we present evidence that motivation and monitoring processes can explain how a person could effectively control themselves in one domain but not others.

The Predictive Ability of General Self-control Scales

Tangney et al. (2004) created a dispositional self-control scale and showed that higher levels of it were associated with better grades, better eating habits, less aggression, and higher emotional well-being. Many subsequent studies have used this scale to predict other life outcomes and behaviors. In a recent metaanalysis, de Ridder, Lensvelt-Mulders, Finkenauer, Stok, and Baumeister (2012) found that the self-control scale significantly predicted a number of self-control outcomes.

In addition to the trait self-control scale, there is a much longer tradition in personality psychology of using trait impulsivity measures to predict self-control outcomes (Sharma, Markon, & Clark, 2014). As discussed in further detail below, a weakness of this tradition is that different researchers have conceptualized impulsivity in dramatically different ways. Nonetheless, Sharma et al.'s (2014) metaanalysis clearly indicates that diverse aspects of impulsivity predict many self-control outcomes.

Processes Underlying Trait Self-control's Effects

Tangney et al. (2004) proposed that their scale measures individual differences in self-control strength. According to this account, individuals high in trait self-control should be more capable of resisting temptations. Consistent with this original account, Schmeichel and Zell (2009) found that individuals high on this scale could resist the urge to blink and tolerate pain more effectively. Friese and Hofmann (2009) also found that these individuals were more capable of resisting automatic unhealthy impulses.

However, a number of more recent findings question the effortful inhibition account of trait self-control. Duckworth and Kern (2011) were unable to successfully link scores on the trait self-control scale with objective cognitive control performance. In addition, Hofmann, Baumeister, Forster, and Vohs (2012) were unable to support the idea that trait self-control predicts success in resisting temptations encountered in daily life. Instead, it appears that people high in trait self-control structure their lives so that temptations are less likely to be encountered. Consistent with this, studies indicate that high self-control individuals report less conflict between goals and desires (Hofmann et al., 2013), take proactive steps to avoid temptations (Ent, Baumeister, & Tice, 2014), and develop habits which allow them to achieve desired goals effortlessly (Galla & Duckworth, 2015).

While more research is clearly needed, these studies suggest that high self-control individuals proactively avoid temptations. While this is certainly an interesting and important aspect of self-control (Fujita, 2011), it suggests that many other individual difference variables are related to self-control. In other words, we encourage a broader perspective on individual differences in self-control than can be assessed using the Tangney et al. (2004) scale.

Consistency in Behavior Across Self-control Domains

Beyond research related to the trait self-control scale, consistencies in behavior across self-control domains have been offered as evidence for the unified view of trait self-control. For example, the criminologists Gottfredson and Hirschi (1990) noted that the same individuals who commit criminal acts also tend to engage in other behaviors suggestive of lesser self-control. They drink and smoke too much. They show up late for work or school. This tends to be true regardless of relevant behaviors' legality.

Clinical psychologists have uncovered similar covariations (see Markon, Kruger, & Watson, 2005). Factor analyses have led to the identification of two factors of clinical symptoms. The first has been labeled *internalizing* and primarily consists of anxiety and mood disorders (eg, depression, generalized anxiety). This factor appears to reflect the pathological end of the neuroticism dimension (Markon et al., 2005). More pertinent to current concerns, the second factor has been labeled *externalizing* and primarily consists of substance abuse and conduct disorders. This factor appears to reflect pathological levels of the normal disinhibition continuum. Disinhibition represents a higher-order personality trait that combines low conscientiousness and low agreeableness from the Big Five model of personality (Markon et al., 2005).

Despite the existence of this general externalizing factor, clinical researchers have posited more specific forms of disinhibition. Multiple studies have found that externalizing includes two lower-order constructs related to overt aggression and covert, nonaggressive behaviors (Markon et al., 2005). These appear to correspond to disagreeable and unconscientious forms of disinhibition, respectively. Below these facets, the more traditional diagnoses represent even more specific types of disinhibition.

Research on normal variations in human personality also points to similar conclusions, in that there are a number of distinct forms of impulsivity. In a metaanalytic factor analysis of published impulsivity scales, Sharma et al. (2014) discovered three relatively distinct traits. The first factor has been labeled sensation seeking. It describes a tendency to engage in dangerous, thrill-seeking activities and is related to extraversion in the Big Five tradition. The second factor has been labeled negative urgency. It describes an inability to think or control one's actions when distressed and is related to neuroticism. The third factor has been labeled disinhibition. It describes a lack of planning and persistence and is related to low conscientiousness.

Sharma et al. (2014) also found that the different forms of impulsivity were all valid in predicting daily impulsive behaviors. Sensation seeking was related to alcohol use and delinquency; Negative urgency predicted substance use more broadly, as well as aggression and delinquency; and disinhibition was widely predictive of all the impulsive behaviors examined. In short, individual differences in self-control cannot be fully captured by one factor.

The Motivation and Ability to Control

How can we make sense of the heterogeneity reviewed earlier? One possibility is that the various types of self-control map onto the various types of cognitive control. However, metaanalyses indicate little to no correlation between self-report questionnaires of self-control/impulsivity and laboratory cognitive control tasks. Sharma et al. (2014) found an overall correlation of $r = 0.02$, and Duckworth and Kern (2011) found an overall correlation of $r = 0.10$. Moreover, these metaanalyses could not locate more precise aspects of self-control or cognitive control which were more consistently related.

Null findings of this type have led some theorists to suggest that self-reported measures of self-control and impulsivity may instead reflect the *motivation* to exert self-control (eg, Karremans et al., 2016). In this view, the higher-order factor of disinhibition (Markon et al., 2005) may reflect a willingness to exert effort toward long-term goals. Lower-level factors may, in turn, reflect more specific goals. For example, agreeable inhibition may reflect the motivation to maintain harmonious social relationships; while conscientious inhibition may reflect one's valuing of long-term achievements. This analysis suggests that both motivation and ability may be important to consider when predicting self-control outcomes.

Consistent with this view, Hofmann, Gschwendner, Friese, Wiers, and Schmitt (2008) found that participants' conscious self-control goals (in this case, related to negative explicit attitudes toward pornography, sweets, and aggression) only predicted self-controlled behavior for individuals high in working memory capacity. By contrast, the behavior of people low in working memory capacity was guided by their implicit attitudes. This pattern has subsequently been replicated for other behaviors such as weight loss (Nederkoorn et al., 2010) and with other indices of cognitive control such as inhibition (Nederkoorn et al., 2010). Cognitive control therefore seems to facilitate self-control by allowing people to act in accordance with their conscious (rather than implicit) goals.

Situation-Specific Recruitment of Cognitive Control

We are accustomed to thinking about cognitive control in terms of abilities (Miyake & Friedman, 2012). However, abilities will not matter if they are not used. Accordingly, the more pertinent question may be *when* people recruit cognitive control. Recent studies have pursued this idea.

Cognitive control models suggest that the most direct predictor of self-control in a specific domain is whether a person recruits cognitive control resources in that domain. To test this idea, we (Wilkowski & Robinson, 2008b) developed a paradigm in which participants are primed with hostile or nonhostile words before completing trials of a cognitive control task. In these studies, we found that individuals low in trait anger exhibit better cognitive control following hostile primes, whereas people high in trait anger do not. This interactive pattern has been found for the flanker task (which is quite similar to the classic Stroop incongruency task; Wilkowski & Robinson, 2008b, Study 2; Wilkowski, Robinson, & Troop-Gordon, 2010, Studies 1–2), the stop-signal task (Wilkowski, 2012), and a task-switching paradigm (Wilkowski & Robinson, 2008b, Study 1). In future research, it will be interesting to see if similar findings will hold in other self-control domains.

Section Summary

In summary, there is some evidence for the unity of individual differences in self-control across domains. Higher-order factors such as externalizing or disinhibition emerge in many factor analyses. Nonetheless, it is necessary to postulate more specific, lower-order factors to fully understand individual differences in self-control. Scales measuring self-control or impulsivity do not show clear correspondence with performance on cognitive control tasks, so they may instead reflect the motivation to engage in self-control. Consistent with this, motivation interacts with cognitive control in predicting self-control in specific domains. A person's tendencies to recruit cognitive control in a specific situation may prove to be the most direct predictor of self-control outcomes in the same domain.

IMPROVING SELF-CONTROL

Given what we have learned about individual differences in self-control, how can we use this knowledge to increase people's self-control? The strength model has suggested that repeatedly engaging in self-control tasks will eventually strengthen the resource underlying self-control (Baumeister et al., 2007). Several studies have tested this possibility by asking participants to engage in self-control training tasks (eg, using one's nondominant hand) for several weeks. While many studies have found improvements in self-control, Inzlicht and Berkman (2015) have presented a metaanalysis questioning the robustness of these results (see Shipstead, ReMiyakedick, & Engle, 2012, for evidence of a similar state of affairs in efforts to enhance working memory capacity). While a full consideration of these training protocols is beyond the scope of this chapter, we would like to briefly consider how a cognitive control framework may inform and improve self-control training protocols. In this connection, we present four points.

Importance of Monitoring

If the need for self-control goes unnoticed, efforts toward self-control will not be initiated. Thus, monitoring processes are critical to self-control. In support of this point, there is now a sizeable literature showing that mindfulness-based interventions effectively improve many self-control outcomes (Brown et al., 2007). These interventions aim to facilitate awareness of one's body and one's surroundings and are believed to work (at least in part) because they improve monitoring processes (Teper et al., 2013).

The Challenge of Cross-Domain Generalization

A major conclusion of our review is that individual differences in self-control are not entirely unitary. Thus, a critical question is whether self-control training in one domain will generalize to another domain. For example, asking participants to use their nondominant hand may cultivate their ability to maintain this goal in memory, recognize stimuli relevant to this goal (eg, doorknobs), recognize errors in achieving this goal (eg, "Oops! I almost used my right hand!"), and implement top-down control over behavior to support this goal (eg, left-hand usage). However, these processes may not transfer to other goals. This problem has clearly surfaced in the working memory training research, where practice on a spatial n-back memory task has sometimes failed to improve performance on the extremely similar verbal n-back task (see Shipstead et al., 2012). It has been suggested that continual practice at one idiosyncratic task may automatize strategies which improve performance only for that one narrow task. Similar generalization problems may occur with self-control training.

The Role of Motivation

If a person is unmotivated to control themselves in a particular domain, self-control training seems unlikely to have much of an effect. Even when people are motivated, one must consider the nature of the motivation. This point emerges from a recent series of studies by Denson et al. (2015). These authors administered self-control training protocols and examined their impact on aggression. When participants had nonaggressive goals (eg, to be compassionate to others), self-control training reduced aggression. However, when participants had aggressive goals (eg, to prevent others from taking advantage of them), self-control training actually *increased* aggression. Null effects for training may often occur because different people have different goals.

Domain-Specific Training

Given difficulties with cross-domain generalization and motivation, it may be more productive to improve self-control in one domain of interest. Along these lines, Wilkowski, Crowe, and Ferguson (2015) recently designed a procedure that trained participants to recruit cognitive control in aggressive situations specifically. This manipulation effectively reduced behavioral aggression among people automatically prone to such acts. Houben and colleagues developed similar procedures to target unhealthy eating (Houben, 2011) and heavy alcohol usage (Houben, Nederkoorn, Wiers, & Jansen, 2011). This work suggests that it may be more fruitful to encourage participants to control themselves in specific circumstances than to improve their domain-general self-control abilities.

COMPARISON TO THE STRENGTH MODEL

The strength model used an elegant metaphor to draw attention to an important aspect of human functioning (Baumeister et al., 2007). The model has been immensely successful. It has inspired volumes of research on an impressive array of variables, from Stroop performance to romantic relationships. This book is a further testament to the influence of the model.

As research progresses, though, it is increasingly important to understand the processes underlying self-control. Attempts to use the original muscle metaphor to do so have not always led to the expected results. For example, while glucose was once thought to be the source of self-control strength (Gailliot et al., 2007), recent evidence suggests that this is not the case (Molden et al., 2012). As researchers attempt to specify the processes underlying self-control, it may be useful to realize that the muscle metaphor is, in the end, just a metaphor. It sheds light on some aspects of self-control, but leaves other aspects of self-control in the dark.

In this connection, we offer the following suggestions for the broader literature on self-control. First, in agreement with the classic strength model, a cognitive control perspective suggests that self-control relies on limited resources. However, these limited capacity resources are not monolithic in nature. Furthermore, they are identified with the prefrontal cortex rather than glucose. Because this region uses recurrent excitatory connections to maintain task-relevant information in an active state (Hazy et al., 2007), it can only complete one cognitive control task at a time. This creates a bottleneck that is evident when participants seek to perform two cognitive control tasks simultaneously (see Enger, 2008).

Because the cognitive control perspective differs in its conceptualization of these resources, it does not suggest that resources grow smaller with use (cf. Kurzban, Duckworth, Kable, & Myers, 2013). Instead, this perspective suggests that ego depletion effects may be due to changes in motivation and monitoring. Because self-control relies on a limited resource, the continual use of this resource for one goal detracts from other goals. Thus, people's motivation and monitoring efforts shift from one goal (eg, completing a psychological study for course credit) to another goal (eg, daydreaming and planning for other upcoming events) (cf. Chapters 13, 18); Inzlicht & Berkman, 2016).

SUMMARY AND CONCLUSION

In this chapter, we reviewed research which has used cognitive control models to understand individual differences in self-control. This analysis suggests at least three important conclusions. First, monitoring is critically important to self-control. If one is oblivious of the need for control, control will not be implemented. Second, individual differences in self-control are not fully consistent across all domains. Chris Farley may have simply not cared to regulate his cravings for drugs, alcohol, or unhealthy foods, but he was motivated to use self-control to excel in his profession. Finally, the resources underlying self-control operations do not appear to be entirely unitary. For example, it is possible that Farley had excellent updating abilities but poor inhibition abilities. This could have allowed him to memorize lines and adapt his routine, but left him unable to control his impulses. We suggest that these three critical insights may have broader relevance to improving self-control training and understanding ego depletion effects.

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