# Chapter 8
# The Strength Model of Self-Control: Recent Advances and Implications for Public Health

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## Introduction

Being able to control basic inner drives, impulses, and 'dominant' responses is a uniquely 'human' trait that enables people to pursue long-term goals at the expense of short-term outcomes. Such acts of *self-regulation* enable the initiation and maintenance of goal-directed behaviors that lead to adaptive outcomes such as success in the workplace and in education, stable and cohesive interpersonal relationships, less psychopathology, less anti-social behaviors, and better health (de Ridder et al. 2012; Metcalfe and Mischel 1999; Tangney et al. 2004; Wills and Stoolmiller 2002). This is extremely relevant to public health as the regulation of health promoting behaviors such as following a healthy diet, engaging in regular physical activity, consuming modest levels of alcohol, and refraining from smoking are all associated with reduced levels of chronic illness (de Ridder et al. 2012; Hagger 2010; Hagger et al. 2009). In contrast, failures in self-regulation are associated with a multitude of maladaptive consequences such as absenteeism in the workplace and at school, conflict and disharmonious personal relationships, personal debt, increased likelihood of antisocial behavior or criminality, lower levels of mental health and psychological wellbeing, and increased risk of illness (Steel 2007; Tangney et al. 2004). This has led psychologists and social neuroscientists to study the factors that lead to effective self-regulation of behavior, particularly impulse control and response inhibition, and those associated with poorer regulation (Baumeister and Heatherton 1996). Such an approach directed toward explaining the mechanisms and processes that lead to effective self-regulation with a view to develop means that may counter the deleterious effects of self-regulation failure.

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A prominent approach to the study self-regulation is derived from theories of self-control. Self-control can be considered a subset of self-regulation that encompasses individuals' ability to overcome their 'dominant' responses, such as impulses, habits, temptations, urges, cravings, and drives, in favor of a more distal goal that is adaptive but more effortful and time consuming (Baumeister and Heatherton 1996; Fujita 2011; Hagger et al. 2010a). Self-control can be conceptualized as a 'trait-like' or 'state-like' construct. Trait conceptualizations of self-control suggest that individuals vary in their general capacity to regulate their self and overcome the dominant responses (Baumeister et al. 2006; Tangney et al. 2004). This is contrasted with the state view of self-control on which ability to self-regulate is determined by factors in the environment such as the demands of the task or behavior (Baumeister et al. 1998; Muraven et al. 1998). Both conceptualizations are incorporated in the *strength* model of self-control, an approach that has led to a proliferation of research into self-control and associated processes and mechanisms (Baumeister and Vohs 2007; Baumeister et al. 2007; Hagger et al. 2010a; Muraven and Baumeister 2000).

In the strength model, self-control is conceptualized as a resource or strength which is limited and becomes depleted after a period of self-control 'exertion' (Baumeister et al. 1998; Muraven et al. 1998). The state of self-control resource depletion is considered a temporary one in which individuals will be less able to engage in tasks and activities that require self-control, but such capacity can be restored after a period of rest or recuperation. As its moniker implies, self-control is considered analogous to a muscle. Just as the force exerted by a muscle experiencing a constant workload over time wanes, so self-control resources become diminished when an individual works on tasks that require self-control. The state of reduced capacity for self-control has been termed *ego-depletion*. The model has received a considerable amount of attention in the social science literature over the past decade due to its intuitive appeal and generally robust findings (Baumeister and Vohs 2007; Baumeister et al. 2007). Importantly, the model has been adopted to explain the role of self-regulatory failure in public health contexts, particularly health promoting behavior (Hagger 2010; Hagger et al. 2009). In this chapter, we will provide an up-to-date overview of the basic tenets of the strength model of self-control, the mechanisms responsible for its effects, and associated hypotheses. We will also provide a contemporary overview of the model and its mechanisms, provide an up-to-date overview of recent developments and extensions of the model, outline its relevance to understanding public health issues, and detail some recommendations for practice and future research.

## The Strength Model: Hypotheses and Evidence

According to the strength model, self-control resources are finite and become depleted after an individual engages in a task or activity that demands self-control for a period of time (Baumeister et al. 1998; Muraven et al. 1998). The

ego-depletion effect has been typically tested in laboratory settings using an experimental procedure, known as the *dual-task paradigm*. Participants are asked to engage in an initial task. Participants are randomized to an experimental group which receives a task that requires self control or a control group which receives a task that does not require self control. All participants then engage in a second self-control task in a different domain of self-control to the first. Performance on the second task represents the dependent measure of self-control capacity and, to the extent that performance on the second task is impaired in the experimental group relative to the control group, the researcher has sharp confirmation of the ego-depletion effect. A classic example of a dual task experiment was conducted by Baumeister et al. (1998) in the seminal work that predicated the ego-depletion effect. Participants were shown into a laboratory which was filled with the aroma of freshly baked cookies and seated behind a table on which was placed two plates of food: tempting cookies and bland radishes. Participants in the self-control group were asked to taste the cookies and leave the radishes while those in the experimental (ego-depletion) group were asked to taste the radishes only and leave the cookies. They were then asked to engage in a frustrating figure-tracing task that was rigged so as to be impossible to solve. Consistent with hypotheses, those who were asked to resist the cookies persisted for less time on the figure-tracing task than those able to taste the cookies. Participants had to exert considerable self-control in resisting the cookies which was hypothesized to deplete their resources leaving their capacity impaired for the figure tracing task.

The ego depletion effect has been tested in numerous studies using self-control tasks from in a number of different domains including impulse suppression (e.g., handgrip strength task, Stroop colour naming task), cognitive processing (e.g., digit-span task), emotion suppression (e.g., active moderation of facial expressions when viewing emotion-evoking stimuli), through suppression (e.g., suppression of unwanted thoughts), social processing (e.g., resisting making racial or sexual stereotypes, engaging in demanding social interaction), controlling attention (e.g., vigilance tasks), and choice and volition (e.g., making consumer choices). These findings not only support the ego-depletion hypothesis but also corroborate a key corollary of the model that acts of self-control are governed by a unitary resource that generalizes to multiple domains.

We conducted a meta-analysis to synthesize the research on the ego-depletion effect. Out analysis revealed that the ego-depletion effect was medium-to-large in magnitude and consistent across task domains (Hagger et al. 2010a). Furthermore, the effect has been replicated in numerous behavioral domains including health (e.g., Friese et al. 2008; Martin Ginis and Bray 2011; Teunissen et al. 2012), education (e.g., Bertrams et al. 2011; Price and Yates 2010), occupation (e.g., Chan and Wan 2012; Schmidt and Neubach 2010), financial management (e.g., Boucher and Kofos 2012; Oaten and Cheng 2007), social interaction (e.g., Ciarocco et al. 2012; DeWall et al. 2010; Gailliot and Baumeister 2007; Tyler 2008), and consumer behavior (e.g., Hofmann et al. 2008; Sultan et al. 2012; Usta and Häubl 2011). Overall, a considerable amount of research has supported the basic premise of the ego-depletion effect and the primary tenet of strength model.

## *Additional Hypotheses*

The strength metaphor has also given rise to several additional hypotheses consistent with self-control as a unitary, limited resource. These include the tenet that the depletion of self-control strength is a relatively short-term phenomenon and can recover relatively quickly after a period of rest or recovery, the premise that when resources are scarce individuals will conserve their self-control resources for times of extreme need, and the proposal that training on self-control tasks can improve self-control capacity and promote better self-control under conditions of ego-depletion. We will visit each of these hypotheses in turn and evaluate the evidence to support them.

### The Recovery Hypothesis

In keeping with the self-control-as-a-muscle metaphor, it has been proposed that once depleted an individuals capacity for self-control will be reduced, as indicated by impaired performance on self-control tasks post-depletion, unless sufficient rest is provided to for recovery. To date there is only one study that has tested this hypothesis. Tyler and Burns (2008) revealed that an extended period between the two tasks in a two-task paradigm led to much better second-task performance among the rested performers relative to those not given a rest. We endeavoured to provide additional support in our meta-analysis by examining whether longer or shorter periods between tasks in the dual task paradigm would affect self-control performance (Hagger et al. 2010a). Specifically, we examined whether studies that required participants to complete questionnaires or engage in filler tasks between the two tasks, indicating increased recovery time, led to better performance on the second task compared to studies in which participants who did not complete questionnaire tasks or fillers. Our results did not reveal any differences, although it must be acknowledged that ours was a relatively crude measure of the time gap between tasks. So, overall, only Tyler and Burns' study has supported this hypothesis and there is clearly a need for additional research to corroborate the role of recovery period in the replenishment of self-control resources.

Interestingly, the recovery of self-control resources does not seem to be confined to rest alone. In a second experiment, Tyler and Burns (2008) subjected participants to a 'relaxing music' condition relative to a 'quiet rest' condition between tasks in a dual-task paradigm experiment. Results revealed that participants in the relaxation condition also performed better on the second task relative to the 'quiet rest' participants. Similarly, a recent study demonstrated that engaging in mindfulness meditation showed no impairment of self-control performance on the second self-control task after depletion while depleted participants demonstrated the expected depletion pattern (Friese et al. 2012). These results suggest that replenishment of self-control resources is also dependent on the quality or nature of that recovery protocol as opposed to rest alone. Both these findings appear to

be consistent with the strength metaphor, as both time and quality of recovery are considered important to the replenishment of strength.

One of the issues arising from the analysis of the relatively limited data available on the recovery hypothesis, is the fact that tests of the ego-depletion effect in the confines of the strength model have generally been confined to tasks of a very short-term duration. Our analysis of dual-task paradigm tests of the model has revealed that the typical duration of self-control tasks was less than 10 min with very little variation and this duration was only weakly and non-significantly related to the ego-depletion effect size. Research in vigilance tasks and the cognitive fatigue literature have given some indication that serious decrements in task performance occur after long-term engagement in tasks typically associated with requiring self-control, there has, to date, been no research examining the effect of self-control task duration on the extent of depletion. In addition, research should also investigate whether variations in the length of the recovery period is proportional to the extent of the recovery of self-control resources. This seemed to be the finding of Tyler and Burns who found that varying rest periods led to incrementally better performance on the second self-control task. This should be a priority for future research examining the effect of recovery on self-control resource depletion.

### The Conservation Hypothesis

Initial tests of the ego-depletion effect implied that self-control capacity was impaired because resources were near exhaustion. Subsequent tests have suggested that depletion of self-control resources is really only partial, meaning that resources are only scarce and lacking in availability rather than near to exhaustion. This implies that depletion is really due to an unwillingness or inability to commit remaining resources to additional demands post depletion. Testing this notion, Muraven et al. (2006) revealed that depleted individuals informed that they would be required to engage in future self-control tasks performed significantly worse on follow-up self-control tasks compared to participants who received no information on future tasks. This was proposed as evidence that individuals are motivated, consciously or not, to conserve self-control resources for future demand.

Consistent with the conservation hypothesis and the partial depletion rather than near exhaustion proposal, it was hypothesized that individuals should be able to commit their scarce self-control resources to performing self-control tasks post-depletion provided they have sufficient motivation or incentive to do so. Supporting this notion, a number of studies have indicated that providing external rewards or personal incentives to participants to perform subsequent self-control tasks leads to better self-control under depletion compared to participants not furnished with any motivational contingency (Moller et al. 2006; Muraven 2008; Muraven et al. 2008; Muraven and Slessareva 2003). The mechanism responsible for these findings is unclear. Research has suggested that self-efficacy and confidence on tasks

is not related to performance on self-control tasks post depletion (Wallace and Baumeister 2002), so it appears that confidence toward performing the tasks is unlikely to be the mechanism. Muraven and Slessareva (2003) claim that the motivational research does support an alternative explanation that self-control resource depletion is really caused by a lack of motivation because the effects of the incentives are confined to depleted and not non-depleted participants, and argues that it is motivation commit the resources that determines performance on self-control tasks under depletion rather than the effect being mediated by motivation per se. However, the role of motivation in self-control resource depletion remains a controversial one, and there is still debate as to whether self-control is really due to a unitary, limited resource at all. This will be revisited in the *Mechanisms and Processes* section of this chapter.

### The Training Hypothesis

There now exists substantial evidence that training or practice on self-control resource depletion can lead to better self-control performance over time. According to the model, training self-control should improve self-control task performance under conditions of depletion by improving the efficiency or availability of self-control resources. A number of studies have used innovative means to train self-control strength and examine the effects on self-control task performance under depletion. Research has shown that engaging in short-term (e.g., controlling speech, using the non-dominant hand, or even regular rinsing with full-strength mouthwash) or long-term (e.g., engaging in programs of exercise, study, or financial management) lead to improved performance on self-control tasks under depletion in the context of a dual-task paradigm (Hui et al. 2009; Muraven et al. 1999; Oaten and Cheng 2006a, b, 2007; Sultan et al. 2012).

Interestingly, our meta-analysis revealed that long-term training studies have been shown to be more effective than short-term training in improving self-control capacity and also on behaviors beyond the experimental tasks within the dual-task paradigm such as dieting, smoking, and exercise (Hagger et al. 2010a). Such research is extremely appealing to those interested in developing behavior-change interventions to promote adaptive outcomes like weight loss or sound financial management. The research implies that training the self-control 'strength' is effective in producing better self-control performance. The mechanisms behind these effects remain elusive and also the longevity of the training effects has yet to be ascertained. Furthermore, it is unclear why some training is effective in improving self-control resource depletion but individuals who are engaged in chronic self-control tasks such as dieters seem to be more vulnerable to self-control resource depletion. It is possible that training needs to involved short-term, discrete, successful performance of self-control tasks to yield important improvements in self-control capacity while long-term, chronic, and unsuccessful self-control experiences undermine self-control capacity (Hagger et al. 2010a).

## *Trait Self-Control and Self-Control Strength*

Much of the literature on self-control from the resource depletion perspective has focused on the short-term 'state' depletion of self-control resources in which environmental demands on self-control, manifested in the initial task in dual-task procedure experiments, lead to immediate failure on self-control tasks. However, much of the self-control literature views self-control as a trait-like construct: a generalized capacity that is stable and enduring (de Ridder et al. 2012; Metcalfe and Mischel 1999; Mischel et al. 1989; Tangney et al. 2004; Wills and Dishion 2004; Zabelina et al. 2007). In an attempt to reconcile these literatures, Baumeister et al. (2006) indicate that trait self-control can be unified with the strength model in the sense that trait self-control acts as a moderator of the ego-depletion effect. In other words, individuals may vary in their overall capacity for self-control and this may lead them to be less vulnerable to the state depletion of self-control resources by the tasks typically used to deplete resources. Research examining this moderating effect of trait self-control has been relatively inconclusive, with some studies revealing the moderating effect and others returning null results (Hagger et al. 2010b). There is definitely scope for future research that systematically examines the moderating role of trait self-control on self-control resource depletion and, most importantly, examining the extent to which high self-control provides a 'protective' effect from the deleterious effect of depletion on self-control task performance.

## *What is a Self-Control Task?*

While the strength model has received considerable support, the model is not without criticisms and controversial debates. Prominent among these debates is what, exactly, constitutes a self-control task. In the original conceptualization of the strength model Baumeister et al. defined self-control in terms of the capacity to overcome impulses, desires, and temptations in keeping with previous reviews of the literature. Self-control was also considered perhaps a more narrow concept that a more global term, self-regulation, which tends to encompass impulse control as well as more global, sustained goal-directed behavior requiring effortful action at the expense or suppression of alternative courses of action (for a complete review see Fujita 2011). The tasks adopted in tests of the strength model usually match closely with the definition provided by Baumeister et al.'s (1998) original conceptualization and our meta-analysis demonstrated that the tasks typically used in the literature on the strength model fall into the distinct categories outlined previously. However, some studies have adopted self-control tasks within the dual-task paradigm which have tended to 'stretch' the definition of a self-control task in that they tap processes originally considered to lie outside the definition of self-control. This is because such tasks require the application of a set, well-learned algorithm rather than having to overcome well-learned response or impulse. For example, some researchers have adopted complex math or computational tasks as depleting task (e.g., Tyler and Burns 2008;

Webb and Sheeran 2003; Wright et al. 2003). Such tasks were originally considered not depleting by Baumeister et al. and were even used as the 'non-depleting' task in the dual-task paradigm control condition (Muraven et al. 1998). Research adopting such depleting tasks claim otherwise and suggest that such tasks tap self-control because they are tedious, effortful and, most importantly, require a person to overcome the urge to quit because of their arduous nature or require complex multiple operations (e.g., division and subtraction in quick succession) rather than single operations.

We recognized this distinction in our recent meta-analysis and even performed a moderator analysis for the ego-depletion effect for studies adopting depleting tasks in the dual task paradigm that adhered to the strict Baumeister definition of self-control compared to those using 'easy or difficult' tasks according to the more elaborated definition. Comparison of these moderator groups revealed no significant difference in the effect size leading us to conclude that both types of task were equally effective in inducing depletion. In conclusion, we suggested that "it seems that effect of self-control depletion on task performance may apply to a broader set of tasks and processes than originally proposed, including difficult or complex tasks" (Hagger et al. 2010a, p. 500). We developed a taxonomy of tasks used a depleting and dependent tasks in dual-task paradigm experiments representing the different domains of self-control, and interested readers are encouraged to read the supplementary materials to our meta-analysis for details (Hagger et al. 2010a, Appendix A).

However, a question still remains as to the characteristics for these tasks necessary to induce self-control resource depletion. For example, how long does an individual have to engage in a self-control task in order to induce depletion? What is the most effective way of developing a 'control' version of a task? Recent research has begun to tackle these kinds of questions. For example, a recent study indicated that performing an attention control task similar to that used by Muraven et al. (1998) for 2 min was insufficient to impair performance on a subsequent anagram-solving task, but performing the task for 4 min or longer was sufficient to induce depletion (Vandellen et al. 2012). Further research is needed to support these findings, but they provide useful initial information to support the premise that task selection and duration are important features of tasks that make them sufficiently demanding of self-control resources to induce ego-depletion.

## Mechanisms and Processes

### *Glucose*

Central to understanding the mechanism that governs self-control 'strength' within Baumeister et al.'s (1998) model is what form, exactly, does the resource take. From the outset of the tests of the model, the resource was defined in metaphorical terms as a form of 'energy' or 'strength', but this definition is unsatisfactory in terms of identifying what it is that become depleted in dual-task experiments. Baumeister et al. (1998) were confident from their initial proposal of the model

that the resource was more than mere metaphor and was associated with some physiological component: "(it is) implausible that ego depletion would have no physiological aspect or correlates at all" (p. 1263). Gailliot et al. (2007) proposed that a possible candidate for the resource was glucose. Specifically, they proposed that self-control tasks would be associated with the utilization of glucose in the brain as a metabolic fuel when performing self-control tasks and that depletion would be associated with falls in the availability of glucose for brain processes. They demonstrated that depletion coincided with falls in blood glucose levels and that supplementation of glucose moderated the ego-depletion effect. However, these results were disputed by authors who demonstrated that the data for the falls in blood glucose were inconclusive and that there was no evidence for fluctuations in glucose availability in the brain (Beedie and Lane 2011; Kurzban 2010).

Following up this research, we have recently demonstrated that the effects of glucose supplementation on attenuating self-control resource depletion may be perceptual rather than metabolic (Hagger and Chatzisarantis 2013). Following exercise physiology research demonstrating that the mere presence of glucose in the oral cavity is sufficient for improving physical endurance, we proposed that tasting, but not ingesting glucose, would lead to individuals overcoming the deleterious effects of self-control resource depletion. We adopted a novel 'mouth rinse' procedure in which participants tasted, but did not ingest, either a glucose solution or an artificially sweetened placebo solution, randomly assigned, in between the two self-control tasks in a dual-task paradigm. Results were consistent with Gailliot et al.'s (2007) findings for glucose supplementation such that self-control performance under conditions of depletion was significantly better when participants rinsed their mouths with glucose relative to placebo and that the effect was confined to depleted participants. A possible mechanism for this finding is that oral receptors exclusively sensitive to glucose send afferent signals to brain regions associated with reward, motivation, and conflict monitoring. The results led us to conclude that, because the solutions in Gailliot et al.'s experiments passed through the oral cavity, the effects of glucose supplementation in attenuating ego-depletion may have been due to the sensing of glucose rather than the metabolic explanation provided by Gailliot et al. Therefore, a question exists as to whether glucose is a suitable candidate for the self-control resource in the strength model.

## *Neural Correlates*

Researchers have also aimed to identify neural correlates of effective self-control with the goal of unveiling the regions of the brain that govern effective self-control and become inhibited under ego-depletion. Research adopting neuroimaging techniques such as electroencephalography and functional magnetic resonance imaging have shown that ego-depletion coincides with reduced activity the anterior cingulate cortex (ACC). The ACC has been found to govern a number of processes important for self-control such as conflict monitoring (Botvinick et al. 2004; Inzlicht and Gutsell 2007) and the need for cognitive control (Heatherton 2011; Heatherton

and Wagner 2011; Lorist et al. 2005). Research has shown that engaging in tasks that require self-control, such as the Stroop color-naming task (Leung et al. 2000) and the handgrip strength task (Liu et al. 2003), is associated with activation in the ACC. In addition, EEG studies have found an attenuation of activity in the neural pathways associated with conflict monitoring, the process by which individuals detect and respond to mismatches in actual and intended responses, during performance of self-control tasks under conditions of depletion and mental fatigue (Inzlicht and Gutsell 2007; Lorist et al. 2005). Activation of the conflict-monitoring system is associated with peaks in error-related negativity (ERN), an EEG waveform isolated in the ACC in neuroimaging studies (van Veen and Carter 2002). Weaker ERN signals have been found in participants performing a Stroop task after the prior depletion of self-control resources compared to non-depleted controls (Inzlicht and Gutsell 2007). It seems that the ACC may play an important role in mediating performance on tasks requiring self-control.

In contrast, a recent fMRI study examining the regions of the brain that may be implicated in self-control resource depletion revealed deficits in the dorsolateral prefrontal cortex (DPFC) but no deficits in ACC activity (Hedgcock et al. 2012). The DPFC is responsible for signaling the need for cognitive control rather than conflict monitoring (Heatherton and Wagner 2011). The authors suggested that this region is the most likely candidate to be involved in self-control depletion rather than the ACC, suggesting that it is control rather than conflict monitoring which may be the most important component. This has been suggested in reviews of the neural correlates of ego-depletion (Heatherton 2011; Heatherton and Wagner 2011). At present, the converging evidence from neuroimaging research seems to suggest that both mechanisms may be involved and it is possible that self-control tasks may differ in the extent to which each neural system contributes to controlling the process. If this is the case, then it raises two questions. First, is effective self-control governed by two separate systems such that deficits in either one, or both, leads to ego-depletion? Second, if different self-control tasks are controlled by a separate system, what implications does that have for self-control being determined by a generalized, unitary resource that applies to all tasks? Clearly, this has implications for the strength model. Is it possible that a single resource can account for two separate neural processes that may be involved in self-control performance? We look to further investigations using neuroimaging techniques for different self-control tasks to shed further light on the brain processes associated with self-control resource depletion from the perspective of the strength model.

## Recent Findings: Individual Differences and Cognitive Explanations

Recent research has focused on identifying factors that moderate the ego-depletion effect in an attempt to unveil potential boundary conditions and mechanisms for the effect. The findings have raised questions as to whether the effect is due to a limited

resource and may, instead, be moderated by other cognitive processes. For example, recent studies have revealed that individual differences in beliefs about self-control (Job et al. 2010) and procrastination (Fitzsimons and Finkel 2011), expectancies of the effort required by self-control tasks (Vandellen et al. 2012), and the provision of consistent and misleading feedback regarding the state of self-control resources (Clarkson et al. 2010) moderate the ego-depletion effect. In addition, research has indicated that actual depletion need not take place, and that depletion effect can also be 'acquired' by taking the perspective of someone experiencing self-control resource depletion (Ackerman et al. 2009). These findings suggest that an alternative mechanism for self-control failure may be due to cognitive beliefs about the nature of self-control rather than to the depletion of a finite unitary resource controlled by a physiological mechanism such as glucose availability.

The research groups behind these studies suggest that their findings indicate that self-control resource depletion may be a function of both cognitive processes and a limited resource related to a kind of strength or energy. The results of these studies do not, on their own, rule out the possibility that self-control is governed by a unitary resource, but they do provide evidence that picture is one that is more complex and multiple processes may be involved. For example, it is possible that beliefs play a substantial part in determining a person's self-control capacity on tasks, and that may be a limiting or facilitating factor when it comes to resource availability. These studies are indicative of the intense and innovative research currently being conducted in the area of self-control and, in particular, on the strength or limited resource model. It is clearly an exciting time for research on self-control and the ongoing attention paid to this area will inevitably lead to further evidence that may yield a more elaborated model of self-control that likely encompasses a limited resource model alongside other perspectives.

## Implications for Public Health

Self-regulation is a key variable when it comes to promoting the uptake and maintenance of behaviors associated with good health. Research has demonstrated that high levels of self-control are consistently associated with health-related behaviors (De Ridder et al. 2008; de Ridder et al. 2012). This is because many health-related behaviors such as following a diet low in saturated fat, sustaining physical activity regimen, adhering to proscribed medication, cutting down on alcohol, quitting smoking, and attending appointments to see medical specialists, all require individuals to engage in long-term, goal directed behavior at the expense of short-term gains or resist some sort of immediate temptation or urge (Hagger et al. 2009; Hall and Fong 2007; Hofmann et al. 2008). This could be the temptation to opt for a sedentary pastime (e.g., watching television) instead of going out to jog after a hard day's work or resiting the urge to smoke if trying to quit smoking. Good self-control also means that individuals will likely be successful in regulating their behavior without the need for any external reinforcement or contingency: they will *self-regulate*. This

is important as health interventionists aim to increase the number of people engaging in health related behavior and reduce the financial and logistical costs of providing constant reinforcements or reminders to persuade and cajole individuals into engaging the health-promoting behaviors and avoid health-compromising behaviors.

From the perspective of the strength model, current research has implicated state self-control as having an important impact on decision making with respect to health related behaviors such as physical activity (Hagger et al. 2010b) and eating behaviors (Hagger et al. 2009). This suggests that self-control resource availability may be implicated in the self-regulation of health behavior. Bolstering self-control is therefore likely to have substantive effects in boosting engagement in health promoting behavior and avoiding health-compromising behavior. Fortunately, research has demonstrated that practice and training on self-control can promote self-control on laboratory-based tasks (Hui et al. 2009; Muraven et al. 1999) as well as behaviors associated with good health such as diet, exercise, and alcohol consumption (Oaten and Cheng 2006a, b, 2007). A key recommendation for intervention designs is that simple self-control exercises can have a facilitative effect on behaviors that require self-control. To date much of the research on practice with self-control has used contrived behaviors such as controlling speech or using a non-dominant hand (Hui et al. 2009; Muraven et al. 1999). Such behaviors may be considered impractical or seemingly trivial, the success of the training in promoting better self-control notwithstanding, so research needs to be conducted into more practical means to train self-control. For example, we have recently conducted the trial of a mobile phone application which enables participants to engage in a self-control task (e.g., a Stroop color-naming task) on a regular basis and are prompted to do so by the phone. This has been successful in improving self-control performance after only 2 weeks. Future studies need to be conducted to examine whether such training has a long-term impact of health-related behavior. The current state of the literature suggests that self-control training will have a positive effect in boosting self-control performance and should be considered an element for inclusion in future health behavior-change interventions.

## Conclusions

The strength model of self-control has received considerable attention in the literature due to its relative simplicity and intuitive appeal. Research in a wide variety of domains and tasks has supported the primary hypothesis of the model that self-control is governed by a unitary resource that is finite and becomes depleted after engaging in a period of self-control. There is also support for additional hypotheses that have emerged from the model including the recovery, conservation, and training hypotheses. The mechanisms responsible for the effect are yet to be fully elucidated and the precise nature of the proposed resource is still hotly debated with proposals of glucose and neural correlates receiving considerable attention in the literature. The model has important implications for public health, particularly with

respect to recommendations for interventions to boost self-control. Future research needs to elucidate the mechanisms that underpin self-control resources and focus on identifying effective and practical means to boost self-control in health behavioral contexts.

## Highlights

- A substantive literature supports the conceptualization of self-control as a form of strength or energy that is finite and limits individuals' capacity on tasks requiring self-control.
- The state of self-control resources depletion is known as *ego-depletion*.
- Research also indicates that recovery time moderates the replenishment of self-control resources, the expectation of future self-control leads to a conservation of resources, and repeated practice on self-control tasks improves subsequent performance on self-control tasks.
- Recent research has identified potential moderators of the ego-depletion effect including beliefs about the nature of self-control and the sensing of oral glucose.
- Future research needs to provide evidence to support the efficacy of interventions incorporating training on self-control tasks to improve self-regulation of health-related behaviors and produce long-term outcomes relevant to public health.

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