Opinion

Why self-control seems (but may not be) limited

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Self-control refers to the mental processes that allow people to override thoughts and emotions, thus enabling behavior to vary adaptively from moment to moment. Dominating contemporary research on this topic is the viewpoint that self-control relies upon a limited resource, such that engaging in acts of restraint depletes this inner capacity and undermines subsequent attempts at control (i.e., ego depletion). Noting theoretical and empirical problems with this view, here we advance a competing model that develops a non-resource-based account of self-control. We suggest that apparent regulatory failures reflect the motivated switching of task priorities as people strive to strike an optimal balance between engaging cognitive labor to pursue 'have-to' goals versus preferring cognitive leisure in the pursuit of 'want-to' goals.

Why self-control seems (but may not be) limited

Self-control refers to the mental processes that allow people to override their thoughts, emotions, and behaviors to keep them in line with overarching goals [1]. Whereas cognitive control relies on at least three separate (yet related) executive functions [2] – task switching, working-memory, and inhibition – at its heart, self-control is most clearly related to inhibitory cognitive control, whereby people restrain or inhibit dominant response tendencies, thereby allowing other more appropriate responses. Although inhibitory control is often assessed using seemingly trivial laboratory tasks (e.g., color naming), it can predict an impressive variety of behaviors of both personal and societal significance, including weight gain [3], sexual infidelity [4], problem gambling [5], and college grades [6], among many others [7].

In a seminal treatment of this topic, Baumeister and colleagues [1,8,9] advanced a resource model of self-control that sets an important limit on regulatory processing; specifically, a refractory period during which time control is less likely to succeed. Thus, as opposed to a parallel processing limit for working memory, which is well established in the field [10], the resource model refers to a sequential or temporal processing limit. Crucially, the model posits that restraint is based on some limited resource or energy, such that engaging self-control quickly consumes this inner capacity, leaving one in a state of 'ego depletion' (see Glossary). In this depleted state, further attempts at self-control are prone to failure.

The resource model is highly influential. It has informed work in most subfields of psychology and human neuroscience [11–13] as well as the related disciplines of behavioral economics [14] and organizational/consumer behavior [15–17]. It also recently took center stage in a bestselling book on self-control [18]. Mounting evidence makes clear, however, that the model is in need of major revision. The goal of this review is to do just that. In brief, we propose that the refractory period of self-control is the product of evolutionary pressures motivating organisms to balance their desires for exploitation versus exploration [19]; this adaptive function translates further to a natural tendency to seek a balance between desires for externally rewarded labor versus inherently rewarding leisure [20]. From this standpoint, self-control failure is less about resource depletion and more about the motivated switching of task priorities from 'have-to' to 'want-to' goals.

Problems with the resource model of self-control

Nearly 30 years ago, David Navon tried to dispatch the concept of resources as it was then used in the psychology of attention [21]. He called resources 'theoretical soup stones',

Glossary

Ego depletion: a state in which people are temporarily less successful at self-control. Although ego depletion is typically attributed to a short-term loss of mental energy due to previous efforts at control, we propose that ego depletion may instead be driven by effort-induced shifts in motivation, attention, and emotion.
Glucose: an important carbohydrate or sugar that is absorbed directly into the bloodstream during digestion. Glucose is widely used by many organisms as a cellular source of energy.
Mental fatigue: a subjective feeling of tiredness resulting from prolonged periods of cognitive activity that diminishes cognitive performance over time. Although mental fatigue is typically viewed as an unwanted byproduct of work that is caused by the depletion of energy, modern treatments suggest that fatigue is an emotion with the adaptive function of preventing fixation on current activities and redirecting attention toward behaviors with higher potential utility.
Self-control: the capacity to override or alter one's predominant (pre-potent, automatic) response tendencies. Akin to the colloquial notion of willpower. Self-control is closely aligned with (but not limited to) response inhibition.

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which are theoretical constructs that seem essential to understanding a phenomenon, but are actually unnecessary and provide little to no explanatory power (similar to how the stone was not needed to make soup in the fable of the hungry travelers). According to Navon, resources are seductive concepts that are easy to understand but are also vague, malleable, and, if given certain qualities, unfalsifiable. As we detail below, accumulating evidence suggests that self-control can be readily understood without recourse to resources.

To date, over 100 studies appear to be consistent with the notion that self-control is based on a limited resource. When participants engage in a motivationally demanding activity at Time 1, performance typically deteriorates on a different task at Time 2 [22]. For example, when participants attempt to restrain their emotions while watching a film, they experience difficulty sustaining mental representations in working memory [23] or inhibiting pre-potent responses on a subsequent task [24]. Studies using this sequential task paradigm have convinced researchers around the world that self-control is limited and relies on finite resources [22]. Challenging this viewpoint, here we propose that self-control merely seems limited, with motivational factors playing a pivotal role.

A first source of skepticism about the resource concept in explaining self-control is that most experiments do not observe resource depletion directly. Rather, researchers infer its presence or absence based on patterns of performance on the second of two self-control tasks [22]. Although this inference sits comfortably with the notion of resource dependence, it is also consistent with alternative formulations that arguably have greater theoretical and biological plausibility.

Thus far, the only direct attempt to measure the putative resource comes from work exploring glucose [25]. These studies suggest that engaging in a motivationally demanding task leads to measurable drops in blood glucose, and these in turn mediate the reductions in self-control attributed to ego depletion [26]. These observations initially appeared to vindicate the resource model, but upon closer inspection notable limitations have emerged [27–30] (Box 1). Chief among these is the failure to replicate evidence that cognitive exertion actually lowers blood glucose levels [31].

At the same time as the identity of the crucial energy source remains in doubt, findings have accumulated that are inconsistent with the resource account, thereby supplying a second source of skepticism. Studies have shown that increased task motivation [32], perceptions of vitality [33], and beliefs that self-control is unlimited [34] can all attenuate the depletion effect. Other 'intervention' studies have demonstrated that smoking cigarettes [35], watching a favorite television program [36], affirming some core value [37], or even praying [38] similarly defend against the reductions in self-control observed in the sequential task paradigm. If self-control is based on a finite (but renewable) resource, it is difficult to understand how changing perceptions or watching television can instantly replenish self-regulatory capacity.

Third and last, the resource model may be functionally implausible [28,39]. Although there may be some evolutionary advantages to a system that discourages individuals from overriding hard-wired response tendencies [26], early humans would have certainly needed to engage in self-control to override strong hard-wired responses (e.g., fear) to eat, procreate, and secure safe shelter [28]. Natural selection should have thus favored organisms that could engage self-control flexibly, in accordance with personal priorities, and for long periods. There are real advantages to a system that can put a brake on exploitation in favor of exploration [19,39]; however, it would make little sense for such a brake to be based on capacity limits as opposed to changing motivational priorities [28]. Given these three problems, we question the necessity and sufficiency of the resource metaphor for explaining self-control, and present a process model that develops a non-resource-based account of the apparent limits of self-control.

Box 1. Glucose and self-control

Glucose supplies energy for diverse activities of the body and brain. Gailliot and colleagues [26] reasoned that glucose may be the physical basis of the hypothetical resource at the core of the resource model of control. They found that (i) engaging in self-control increases carbohydrate metabolization and consumes inordinate amounts of blood glucose compared to less effortful tasks, (ii) drops in glucose levels account for the behavioral decrements of engaging in control, and (iii) consuming beverages laden with glucose increases levels of blood glucose and counteracts these behavioral decrements. This evidence thus strongly suggested that glucose is vital for self-control.

However, attempts to replicate these findings – particularly the finding that self-control increases carbohydrate metabolization in the form of lower blood glucose levels – have met with mixed success [27,31,75]. For example, in one notable replication attempt, exerting self-control did not lower levels of blood glucose [31]. What makes this study notable is that it assessed carbohydrate metabolization with highly precise measurements of blood glucose levels under carefully standardized conditions; by contrast, the original studies employed commercially available Accu-Chek blood glucose monitors (Roche Diagnostics, Basel, Switzerland) whose results are relatively less precise [28,76].

Although cognitive effort might not decrease levels of blood glucose, glucose consumption does seem to enhance performance on tasks that require self-control, as revealed by several studies. For example, manipulated increases in blood glucose have been observed to increase the inhibition of aggressive impulses [77] and to enhance working memory [78]. Glucose consumption has even been reported to improve control in dogs [79].

Such evidence confirms that glucose is relevant for self-control, but the manner in which glucose enhances control is unclear. Accumulating evidence suggests that simply rinsing the mouth with a glucose-laden liquid – without consuming it – can enhance cognitive control [31,80,81]. These results strongly suggest that the response of body and brain to glucose in the oral cavity, and not actual carbohydrate metabolization, is a key to its salutary effects. Viewed in this light, glucose does not appear to be the physical basis of the resource for self-control.

The process model of self-control depletion

Extending and elaborating our earlier work on the topic [40], the process model integrates ideas from multiple lines of research and theory, including the opportunity cost model of performance [39], labor/leisure tradeoffs in cognitive control [20], and the psychology of fatigue [41]. What is noteworthy about our elaborated process model is that it addresses the apparent limits of control at multiple levels of analysis [42] (Figure 1). When asking why engaging in self-control at Time 1 diminishes restraint at Time 2, both

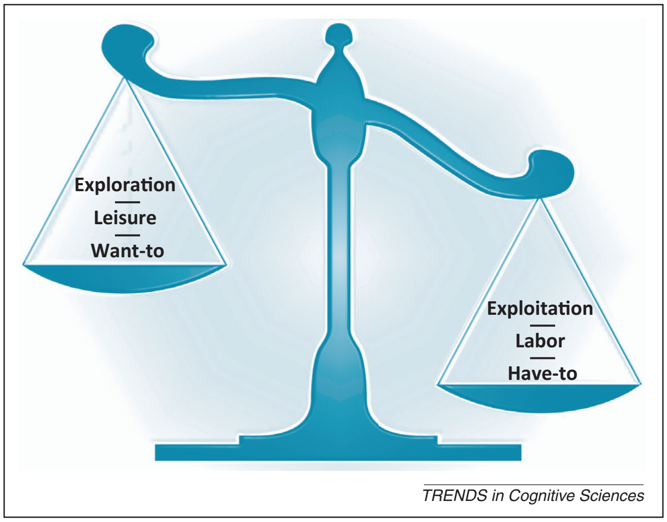

Figure 1. The imbalance of motivations (at multiple levels of analysis) contributing to the refractory period of self-control. According to the elaborated process model, the refractory period of self-control is the product of an imbalance between motivational needs for exploration, leisure, and 'want-to' goals after having exerted effort on exploitation, labor, and 'have-to' goals. This desire for balance originates from evolutionary pressures motivating organisms to trade-off their desires for exploitation of a known resource against exploration of potentially new resources (ultimate level). This adaptive function translates to a natural tendency to seek a balance between desires for externally rewarded labor versus inherently rewarding leisure (intermediate level). This motivated switching between labor and leisure is evolutionarily adaptive because it allows an organism not only to mentally engage in a task to attain rewards and resources, but also to disengage from it and seek activities that may be even more gratifying. These ultimate and intermediate accounts lay the groundwork for a process account suggesting that initial acts of control lead to shifts in motivation away from 'have-to' or 'ought-to' goals, and toward 'want-to' goals (proximate level). Thus, previous acts of cognitive effort lead people to prefer activities that they deem enjoyable or gratifying over activities that they feel they ought to carry out because they correspond to some obligation or introjected goal.

ultimate and proximate explanations are required [43]; we also suggest that intermediate or meso-level explanations are needed. Ultimate explanations address why there are apparent limits to self-control. Proximate explanations focus on the underlying cognitive and emotional processes that give rise to such effects. Meso-level explanations suggest intermediate processes that translate between abstract evolutionary functions and proximate cognitive operations.

Ultimate account

The process model is based on evolutionary considerations that lead organisms to prefer an optimal trade-off between exploitation and exploration [44], whereby the value of exploiting established sources of reward is pitted against the utility of exploring the environment for new opportunities. The need to balance exploitation with exploration is confronted at all levels of behavior and is not limited to humans (e.g., foraging animals deciding whether to continue harvesting a known source of food or to survey the land for other stores of food [39]). Balancing this trade-off involves regulating the extent to which the control system favors task engagement (exploitation) versus task disengagement and the sampling of other opportunities (exploration). Recent work suggests that the locus coeruleus–norepinephrine system plays an important role in this process [45,46].

Box 2. The psychology of fatigue

Frequently studied but often misunderstood, fatigue plays a central role in the regulation of behavior [82]. Moreover, similar to self-control, influential treatments of the topic have advanced a serious misrepresentation – that fatigue is caused by a loss of energy following excessive work. According to this account, mental energy is the basis of motivation and action, such that when resources are lacking people are less able to pursue their current goals or initiate new activities. As it turns out, however, this viewpoint is fundamentally flawed. After an extensive review of the psychology of fatigue, Robert Hockey [41] proposed a motivational control theory of fatigue, whereby fatigue does not affect task performance through a failure of energy, but by changing the selection and control of goals [52]. Fatigue, according to this view, is an emotion that interrupts current behavior such that alternative options can be entertained.

According to opportunity-cost models, people must balance the costs of task persistence with the benefits of pursuing new activities [39,48,83]. That is, they must decide whether to maintain current goals and behavioral preferences or to switch to new opportunities when they offer greater benefits. Fatigue plays a crucial role in this process of task prioritization, in that feelings of effort signal the opportunity costs of continuing to engage in the current activity. When these costs are excessive, people will turn their attention instead toward a different activity that yields greater benefits. From this perspective, fatigue is the experienced output of motivational systems that signal the need (or not) to re-prioritize one's activities. By interrupting ongoing behavior, fatigue triggers a (likely unconscious) cost–benefit analysis of one's current goals and activities, thus enabling other priorities to compete for access to motivational control [39,52].

In contrast to some [84], but in agreement with others [9], we suggest that ego depletion is a type of short-term mental fatigue. After people have engaged effort – be that for a relatively short period, as in depletion, or for a long period, as in fatigue – they reconsider their motivational priorities, with a bias toward inherently motivating, personally meaningful goals [52]. From this perspective, depletion and fatigue function to maintain the motivational balance between maintaining cognitive effort on externally rewarded 'have-to' goals versus switching to more 'want-to' goals that act as form of cognitive leisure and are more inherently rewarding [19,20].

Intermediate account

Balancing exploitation versus exploration serves an adaptive function that leads to a general tendency to prefer balance between cognitive labor and cognitive leisure, or between mental work and mental rest. According to labor-supply economics [47], the fact that time is limited leads people to prefer some optimal balance between externally rewarded labor and inherently rewarding leisure. Recent research suggests that cognitive control is intrinsically aversive [48], having inherent disutility [49]. Although people will engage in mental work to the extent that it carries some form of external reward (e.g., money, course credit, pleasing an experimenter, etc.) [49], the inherent disutility of mental work accumulates the more one has worked, meaning that ever more external rewards are needed to counteract the aversiveness of work, or else people will gravitate toward inherently rewarding leisure instead [20]. This means that people will tend to avoid cognitive work, even cognitive work on a different task, after initial bouts of effort. Although people generally avoid hard work [50] and cognitive exertion [49], they may be especially unmotivated to engage such effort after having recently worked, instead preferring to pursue more inherently pleasurable activities. Offsetting this tendency, increasing incentives for work decrease its aversiveness [49] and counteract the desire for leisure.

This motivated switching between labor and leisure is evolutionarily adaptive because it allows an organism not only to mentally engage in a task to attain rewards and resources (i.e., exploitation) but also to disengage from it and seek activities that may be even more gratifying (i.e., exploration). From this perspective, depletion may be the motivated switching of task priorities, wherein all forms of mental work become increasingly aversive, making mental leisure increasingly attractive. The feelings of fatigue [22], boredom [51], and negative emotion [22] that accompany depletion, then, may serve the adaptive function of preventing fixation on current activities and redirecting behavior toward other activities with higher inherent utility [39,52] (Box 2).

Proximate account

These ultimate and intermediate accounts lay the groundwork for a proximate, process-based analysis that informs how engaging control at Time 1 leads to less restraint at Time 2 [40]. Based on the tradeoffs identified above, we propose that initial acts of control lead to shifts in motivation away from 'have-to' or 'ought-to' goals and toward 'want-to' goals (Figure 2). 'Have-to' tasks are carried out through a sense of duty or contractual obligation, whereas 'want-to' tasks are carried out because they are personally enjoyable and meaningful [41]; as such, 'want-to' tasks feel easy to perform and to maintain in focal attention [41]. The distinction between 'have-to' and 'want-to', however, is not always clear cut, with some 'want-to' goals (e.g., wanting to lose weight) being more introjected and feeling more similar to 'have-to' goals because they are adopted out of a sense of duty, societal conformity, or guilt instead of anticipated pleasure [53].

According to decades of research on self-determination theory [54], the quality of motivation that people apply to a situation ranges from extrinsic motivation, whereby behavior is performed because of external demand or reward, to intrinsic motivation, whereby behavior is performed because it is inherently enjoyable and rewarding. Thus, when we suggest that depletion leads to a shift from 'have-to' to 'want-to' goals, we are suggesting that earlier acts of cognitive effort lead people to prefer activities that they deem enjoyable or gratifying over activities that they feel they ought to do because they correspond to some external pressure or introjected goal. For example, after initial cognitive exertion, restrained eaters prefer to indulge their sweet tooth rather than adhere to their strict views of what is appropriate to eat [55]. Crucially, this shift from 'have-to' to 'want-to' can be offset when people become (internally or externally) motivated to perform a 'have-to' task [49]. Thus, it is not that people cannot control themselves on some externally mandated task (e.g., name colors, do not read words); it is that they do not feel like controlling themselves, preferring to indulge instead in more

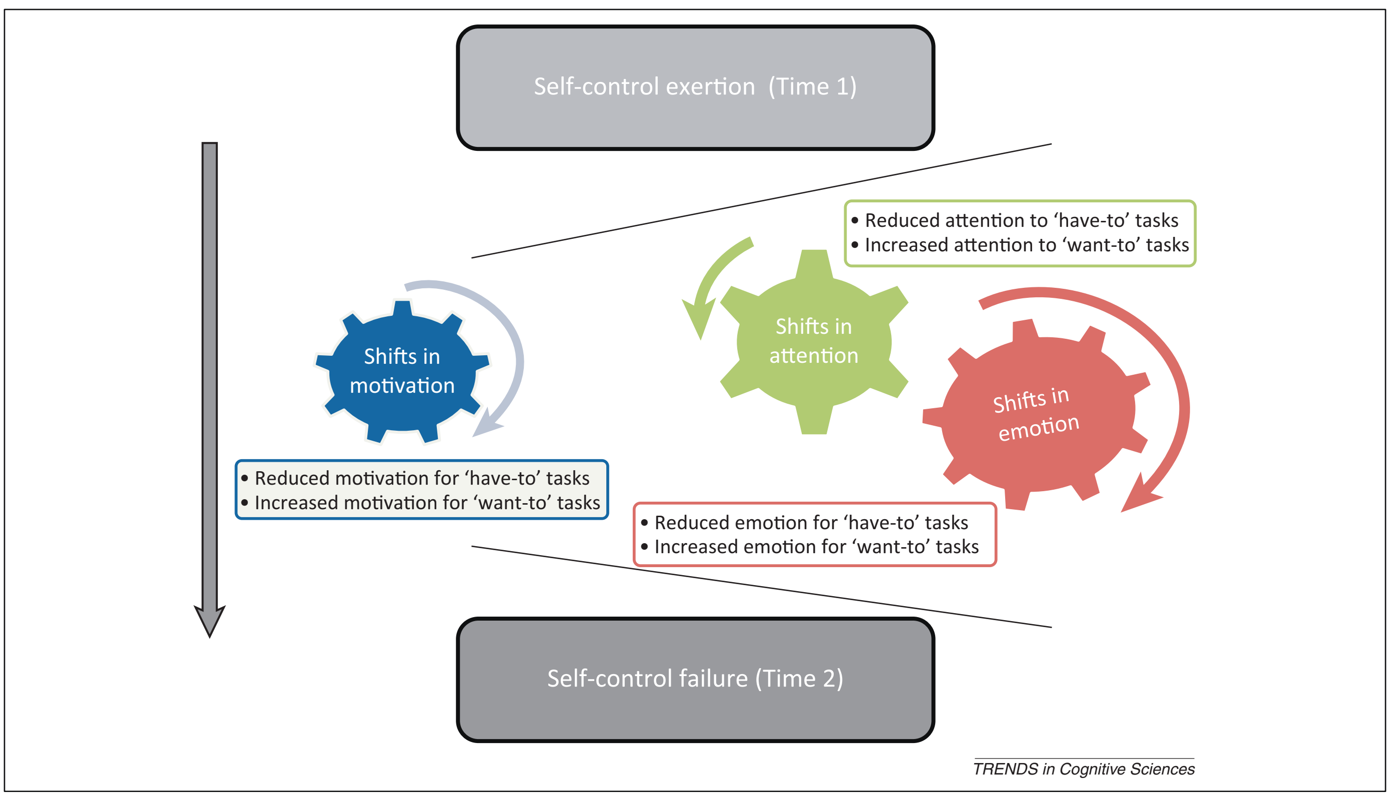

Figure 2. How self-control exertion at Time 1 leads to self-control failure at Time 2. According to the elaborated process model, self-control exertion at Time 1 leads to the motivated switching of task priorities, wherein mental work become increasingly aversive, making mental leisure increasingly attractive. These changing task priorities translate to shifts in motivation away from 'have-to' goals and toward 'want-to' goals. 'Have-to' tasks are carried out through a sense of duty, obligation or guilt, whereas 'want-to' tasks are carried out because they are personally enjoyable and gratifying. Because motivation can be decomposed to a mental representation of a goal-state and the emotion (i.e., valence and arousal) that gives this goal-state vigor, shifts in motivational priorities lead to attendant changes in attention and emotion to 'have-to' versus 'want-to' goals. Thus, self-control exertion at Time 1 alters the salience of (and attention to) 'have-to' versus 'want-to' goals and the intensity of experienced emotions associated with these goals.

inherently enjoyable and easier pursuits (e.g., read words). Similar to fatigue, the effect is driven by reluctance and not incapability [41] (Box 2).

Research is consistent with this motivational viewpoint. Although working hard at Time 1 tends to lead to less control on 'have-to' tasks at Time 2, this effect is attenuated when participants are motivated to perform the Time 2 task [32], have personally invested in the Time 2 task [56], or when they enjoy the Time 1 task [57]. Similarly, although performance tends to falter after continuously performing a task for a long period, it returns to baseline when participants are rewarded for their efforts [58], and remains stable for participants who have some control over and are thus engaged with the task [59]. Motivation, in short, moderates depletion [60]. We suggest that changes in task motivation also mediate depletion [61].

Depletion, however, is not simply less motivation overall. Rather, it is produced by lower motivation to engage in 'have-to' tasks and higher motivation to engage in 'want-to' tasks. Depletion stokes desire [62]. Thus, working hard at Time 1 increases approach motivation, as indexed by self-reported states, impulsive responding, and sensitivity to inherently rewarding, appetitive stimuli [63]. This shift in motivational priorities from 'have-to' to 'want-to' means that depletion can increase the reward value of inherently rewarding stimuli. For example, when depleted dieters see food cues, they show more activity in the orbitofrontal cortex, a brain area associated with coding reward value, compared to non-depleted dieters [64].

As part of the shift in motivational priorities, we suggest that depletion leads to attendant changes in attention and emotion [42]. Motivation can be characterized by both a direction and amplification of behavior toward that direction [65]. Thus, we can decompose motivation to a goal-state and the emotion that gives this goal-state vigor [66,67]. When we propose that depletion leads to shifts in motivation, this suggests that it alters the salience of (and attention to) competing goals and the intensity of experienced emotions associated with these goals. Preliminary evidence is consistent with this view. Depletion leads to lapses in attention on externally mandated 'have-to' tasks [24], as suggested by dampened error-related brain potentials [68] generated by the dorsal anterior cingulate cortex (dACC) [69] and related to the monitoring of cognitive conflict [70]. What is more, these dampened brain potentials partially mediate lapses in attentional control [24]. Given recent advances suggesting that these brain potentials [71,72] and the dACC [73] are sensitive to (and perhaps reflective of) negative affect, another interpretation of the above finding is that depletion dampens emotions related to 'have-to' goals. At the same time, however, depletion amplifies attention and related emotions to intrinsically gratifying 'want-to' goals, such as money [62] and food [63]. Thus, by shifting motivational priorities, depletion shapes attention and emotion to these competing priorities.

Cognitive control without resources

Although not as immediately appealing as the resource model, our account is biologically plausible and consistent with current understanding of how the brain works. Although many pressing questions remain (Box 3), our model can accommodate most of the findings that are incompatible with the resource account [40]. For example, it suggests that watching TV, smoking cigarettes, and affirming core values all undermine depletion because they act as rewards that counteract the decreasing marginal utility of engaging in additional cognitive work. Our model is also generative, suggesting novel and testable hypotheses that would otherwise not be anticipated by the resource account. For example, given our assertion that depletion shifts attention away from 'have-to' goals, we propose that depletion should be attenuated by the external scaffolding of attention on these goals, such as with positive or negative task-feedback. Preliminary evidence is consistent with this view [74]. We further propose that depletion will lead to increased cognitive effort if it is to pursue 'want-to' goals (particularly immediately gratifying ones).

Time is nigh to move beyond theoretical soup-stones and to be more precise about an important facet of cognitive control. By offering ultimate, intermediate, and proximate accounts, our process model can explain the apparent limits of self-control without reference to limited resources. Although self-control does seem to have a refractory period, it is caused by shifting priorities and the increasing aversiveness of cognitive work. It is not caused by some hard cap on control.

Box 3. Outstanding questions

- The process model suggests that 'depletion' is the result of changing task priorities: that initial control leads to shifts in motivation away from 'have-to' goals and toward 'want-to' goals. How important are individual differences to the motivational factors that regulate task selection? There is evidence that individual differences in approach motivation are important [63], but what of other individual differences?
- We have identified explanations for 'depletion' at ultimate, intermediate, and proximate levels of analysis. How are these levels associated with one another? For example, we have suggested that the tradeoff between exploitation/exploration translates to the tradeoff between labor/leisure; however, exploration of new opportunities is not equivalent to engaging in a familiar form of leisure. How, then, are the multiple levels of analysis related?
- Given assertions that people have a need to balance labor versus leisure [20], if people are allowed leisure first, will they then become more willing to engage in rewarded labor? That is, can we increase cognitive effort by allowing people to first engage in leisure?
- How important are subjective factors in determining what labor is and what leisure is? Given individual preferences for various activities, one person's labor may be another person's leisure. Are there objective factors that can divide labor from leisure?
- How do long-term episodes of self-control influence subsequent control? Some evidence suggests that practicing control can increase self-control overall [85], but the precise mechanics of how and when this occurs is still unclear.

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References

1 Baumeister, R.F. *et al.* (2007) The strength model of self-control. *Curr. Dir. Psychol.* 16, 351–355

2 Miyake, A. *et al.* (2000) The unity and diversity of executive functions and their contributions to complex 'frontal lobe' tasks: a latent variable analysis. *Cogn. Psychol.* 41, 49–100
3 Nederkoorn, C. *et al.* (2010) Control yourself or just eat what you like? Weight gain over a year is predicted by an interactive effect of response inhibition and implicit preference for snack foods. *Health Psychol.* 29, 389–393
4 Pronk, T.M. *et al.* (2011) How can you resist? Executive control helps romantically involved individuals to stay faithful. *J. Pers. Soc. Psychol.* 100, 827–837
5 von Hippel *et al.* (2009) Executive functioning and gambling: performance on the trail making test is associated with gambling problems in older adult gamblers. *Aging Neuropsychol. Cogn.* 16, 654–670
6 Hirsh, J.B. and Inzlicht, M. (2010) Error-related negativity predicts academic performance. *Psychophysiology* 47, 192–196
7 Hofmann, W. *et al.* (2012) Executive functions and self-regulation. *Trends Cogn. Sci.* 16, 174–190
8 Baumeister, R.F. and Heatherton, T.F. (1996) Self-regulation failure: an overview. *Psychol. Inq.* 7, 1–15
9 Muraven, M. and Baumeister, R.F. (2000) Self-regulation and depletion of limited resources: does self-control resemble a muscle? *Psychol. Bull.* 126, 247–259
10 Baddeley, A. (2007) *Working Memory, Thought, and Action*, Oxford University Press
11 Heatherton, T.F. and Wagner, D.D. (2011) Cognitive neuroscience of self-regulation failure. *Trends Cogn. Sci.* 15, 132–139
12 Kaplan, S. and Berman, M.G. (2010) Directed attention as a common resource for executive functioning and self-regulation. *Perspect. Psychol. Sci.* 5, 43–57
13 Shamosh, N.A. and Gray, J.R. (2007) The relation between fluid intelligence and self-regulatory depletion. *Cogn. Emot.* 22, 1933–1943
14 Loewenstein, G. and O'Donoghue, T. (2004) *Animal Spirits: Affective and Deliberative Processes in Economic Behavior*, Social Science Research Network, http://ssrn.com/abstract=539843
15 Hofmann, W. *et al.* (2008) Free to buy? Explaining self-control and impulse in consumer behavior. *J. Consum. Psychol.* 19, 22–26
16 Gino, F. *et al.* (2011) Unable to resist temptation: how self-control depletion promotes unethical behavior. *Organ. Behav. Hum. Decis. Process.* 115, 191–203
17 Pocheptsova, A. *et al.* (2009) Deciding without resources: resource depletion and choice in context. *J. Mark. Res.* 46, 344–355
18 Baumeister, R.F. and Tierney, J. (2011) *Willpower: Rediscovering the Greatest Human Strength*, Penguin
19 Cohen, J.D. *et al.* (2007) Should I stay or should I go? How the human brain manages the trade-off between exploitation and exploration. *Philos. Trans. R. Soc. B: Biol. Sci.* 362, 933–942
20 Kool, W. and Botvinick, M. (2012) A labor/leisure tradeoff in cognitive control. *J. Exp. Psychol. Gen.* http://dx.doi.org/10.1037/a0031048
21 Navon, D. (1984) Resources – a theoretical soup stone? *Psychol. Rev.* 91, 226–234
22 Hagger, M.S. *et al.* (2010) Ego depletion and the strength model of self-control: a meta-analysis. *Psychol. Bull.* 136, 495–525
23 Schmeichel, B.J. (2007) Attention control, memory updating, and emotion regulation temporarily reduce the capacity for executive control. *J. Exp. Psychol. Gen.* 136, 241–255
24 Inzlicht, M. and Gutsell, J.N. (2007) Running on empty neural signals for self-control failure. *Psychol. Sci.* 19, 933–937
25 Gailliot, M.T. *et al.* (2007) Self-control relies on glucose as a limited energy source: willpower is more than a metaphor. *J. Pers. Soc. Psychol.* 92, 325–336
26 Gailliot, M.T. and Baumeister, R.F. (2007) The physiology of willpower: linking blood glucose to self-control. *Pers. Soc. Psychol. Rev.* 11, 303–327
27 Kurzban, R. (2010) Does the brain consume additional glucose during self-control tasks? *Evol. Psychol.* 8, 229–244
28 Beedie, C.J. and Lane, A.M. (2012) The role of glucose in self-control: another look at the evidence and an alternative conceptualization. *Pers. Soc. Psychol. Rev.* 16, 143–153
29 Schimmack, U. (2012) The ironic effect of significant results on the credibility of multiple-study articles. *Psychol. Methods* 17, 551–566
30 Job, V. *et al.* (2013) Beliefs about willpower determine the impact of glucose on self-control. *Proc. Natl. Acad. Sci. U.S.A.* 110, 14937–14942
31 Molden, D.C. *et al.* (2012) Motivational versus metabolic effects of carbohydrates on self-control. *Psychol. Sci.* 23, 1137–1144
32 Muraven, M. and Slessareva, E. (2003) Mechanisms of self-control failure: motivation and limited resources. *Pers. Soc. Psychol. Bull.* 29, 894–906
33 Clarkson, J.J. *et al.* (2010) When perception is more than reality: the effects of perceived versus actual resource depletion on self-regulatory behavior. *J. Pers. Soc. Psychol.* 98, 29–46
34 Job, V. *et al.* (2010) Ego depletion – is it all in your head? Implicit theories about willpower affect self-regulation. *Psychol. Sci.* 22, 1686–1693
35 Heckman, B.W. *et al.* (2012) The restorative effects of smoking upon self-control resources: a negative reinforcement pathway. *J. Abnorm. Psychol.* 122, 244–249
36 Derrick, J.L. (2012) Energized by television: familiar fictional worlds restore self-control. *Soc. Psychol. Pers. Sci.* 4, 299–307
37 Schmeichel, B.J. and Vohs, K. (2009) Self-affirmation and self-control: affirming core values counteracts ego depletion. *J. Pers. Soc. Psychol.* 96, 770–782
38 Friese, M. and Wanke, M. (2014) Personal prayer buffers self-control depletion. *J. Exp. Soc. Psychol.* 51, 56–59
39 Kurzban, R. *et al.* (2013) A cost/benefit model of subjective effort and task performance. *Behav. Brain Sci.* 36, 661–726
40 Inzlicht, M. and Schmeichel, B.J. (2012) What is ego depletion? Toward a mechanistic revision of the resource model of self-control. *Perspect. Psychol. Sci.* 7, 450–463
41 Hockey, G.R.J. (2013) *The Psychology of Fatigue: Work, Effort and Control*, Cambridge University Press
42 Inzlicht, M. and Schmeichel, B.J. (2013) Beyond simple utility in predicting self-control fatigue: a proximate alternative to the opportunity cost model. *Behav. Brain Sci.* 36, 695–696
43 Scott-Phillips, T.C. *et al.* (2011) Evolutionary theory and the ultimate–proximate distinction in the human behavioral sciences. *Perspect. Psychol. Sci.* 6, 39–47
44 Tooby, J. and Cosmides, L. (2005) Conceptual foundations of evolutionary psychology. In *Handbook of Evolutionary Psychology* (Buss, D.M., ed.), pp. 5–67, John Wiley & Sons
45 Gilzenrat, M.S. *et al.* (2010) Pupil diameter tracks changes in control state predicted by the adaptive gain theory of locus coeruleus function. *Cogn. Affect. Behav. Neurosci.* 10, 252–269
46 Jepma, M. and Nieuwenhuis, S. (2011) Pupil diameter predicts changes in the exploration–exploitation trade-off: evidence for the adaptive gain theory. *J. Cogn. Neurosci.* 23, 1587–1596
47 Kagel, J.K. *et al.* (1995) *Economic Choice Theory: An Experimental Model of Animal Behavior*, Cambridge University Press
48 Botvinick, M.M. (2007) Conflict monitoring and decision making: reconciling two perspectives on anterior cingulate function. *Cogn. Affect. Behav. Neurosci.* 7, 356–366
49 Kool, W. *et al.* (2010) Decision making and the avoidance of cognitive demand. *J. Exp. Psychol. Gen.* 139, 665–682
50 Hull, C. (1943) *Principles of Behavior*, Appleton–Century–Crofts
51 Alberts, H.J. *et al.* (2011) Fighting self-control failure: overcoming ego depletion by increasing self-awareness. *J. Exp. Soc. Psychol.* 47, 58–62
52 Hockey, G.R.J. (1997) Compensatory control in the regulation of human performance under stress and high workload. A cognitive energetical framework. *Biol. Psychol.* 45, 73–93
53 Sheldon, K.M. and Elliott, A.J. (1998) Not all personal goals are personal: comparing autonomous and controlled reasons for goals as predictors of effort and attainment. *Pers. Soc. Psychol. Bull.* 24, 546–557
54 Deci, E. and Ryan, R. (2002) *Handbook of Self-Determination Research*, University of Rochester Press
55 Vohs, K.D. and Heatherton, T. (2000) Self-regulatory failure: a resource-depletion approach. *Psychol. Sci.* 11, 249–254
56 Legault, L. *et al.* (2009) When internalization leads to automatization: rhe role of self-determination in automatic stereotype suppression and implicit prejudice regulation. *Motiv. Emotion* 33, 10–24
57 Moller, A.C. *et al.* (2006) Choice and ego-depletion: the moderating role of autonomy. *Pers. Soc. Psychol. Bull.* 32, 1024–1036
58 Boksem, M.A. *et al.* (2006) Mental fatigue, motivation and action monitoring. *Biol. Psychol.* 72, 123–132
59 Hockey, G.R.J. and Earle, F. (2006) Control over the scheduling of simulated office work reduces the impact of workload on mental fatigue and task performance. *J. Exp. Psychol. Appl.* 12, 50–65
60 Baumeister, R.F. and Vohs, K.D. (2007) Self-regulation, ego depletion, and motivation. *Soc. Pers. Psychol. Compass* 1, 115–128

61 Robinson, M.D. *et al.* (2010) A cognitive control perspective of self-control strength and its depletion. *Soc. Pers. Psychol. Compass* 4, 199–200
62 Hofmann, W. *et al.* (2012) What people desire, feel conflicted about, and try to resist in everyday life. *Psychol. Sci.* 23, 582–588
63 Schmeichel, B.J. *et al.* (2010) Exercising self-control increases approach motivation. *J. Pers. Soc. Psychol.* 99, 162–173
64 Wagner, D.D. *et al.* (2013) Self-regulatory depletion enhances neural responses to rewards and impairs top-down control. *Psychol. Sci.* 24, 2262–2271
65 Elliot, A.J. (2006) The hierarchical model of approach-avoidance motivation. *Motiv. Emotion* 30, 111–116
66 Tomkins, S.S. (1982) Affect theory. In *Emotion in the Human Face* (2nd edn) (Ekman, P., ed.), pp. 353–395, Cambridge University Press
67 Buck, R. (1999) The biological affects: a typology. *Psychol. Rev.* 106, 301–336
68 Gehring, W.J. *et al.* (1993) A neural system for error detection and compensation. *Psychol. Sci.* 4, 385–390
69 Dehaene, S. *et al.* (1994) Localization of a neural system for error detection and compensation. *Psychol. Sci.* 5, 303–305
70 Botvinick, M.M. *et al.* (2001) Conflict monitoring and cognitive control. *Psychol. Rev.* 108, 624
71 Inzlicht, M. and Al-Khindi, T. (2012) ERN and the placebo: a misattribution approach to studying the arousal properties of the error-related negativity. *J. Exp. Psychol. Gen.* 141, 799–807
72 Proudfit, G.H. *et al.* (2013) Anxiety and error monitoring: the importance of motivation and emotion. *Front. Hum. Neurosci.* 7, 636
73 Shackman, A.J. *et al.* (2011) The integration of negative affect, pain and cognitive control in the cingulate cortex. *Nat. Rev. Neurosci.* 12, 154–167
74 Wan, E.W. and Sternthal, B. (2008) Regulating the effects of depletion through monitoring. *Pers. Soc. Psychol. Bull.* 34, 32–46
75 Dvorak, R.D. and Simons, J.S. (2009) Moderation of resource depletion in the self-control strength model: differing effects of two models of self-control. *Pers. Soc. Psychol. Bull.* 35, 572–583
76 Khan, A.I. *et al.* (2006) The variability of results between point-of-care testing glucose meters and the central laboratory analyzer. *Arch. Pathol. Lab. Med.* 130, 1527–1532
77 Denson, T.F. *et al.* (2010) Glucose consumption decreases impulsive aggression in response to provocation in aggressive individuals. *J. Exp. Soc. Psychol.* 46, 1023–1028
78 Owen, L. *et al.* (2012) The effect of glucose dose and fasting interval on cognitive function: a double-blind, placebo-controlled, six-way crossover study. *Psychopharmacology (Berl.)* 220, 577–589
79 Miller, H.C. *et al.* (2010) Self-control without a 'self'? Common self-control processes in humans and dogs. *Psychol. Sci.* 22, 534–539
80 Hagger, M.S. and Chatzisarantis, N.L. (2013) The sweet taste of success the presence of glucose in the oral cavity moderates the depletion of self-control resources. *Pers. Soc. Psychol. Bull.* 39, 28–42
81 Sanders, M.A. *et al.* (2012) The gargle effect rinsing the mouth with glucose enhances self-control. *Psychol. Sci.* 23, 1470–1472
82 Bartley, S.H. and Chute, E. (1947) *Fatigue and Impairment in Man*, McGraw-Hill
83 Hockey, G.R.J. (2011) A motivational control theory of cognitive fatigue. In *Cognitive Fatigue: Multidisciplinary Perspectives on Current Research and Future Applications* (Ackerman, L.P., ed.), pp. 167–197, American Psychological Association
84 Vohs, K.D. *et al.* (2011) Ego depletion is not just fatigue: evidence from a total sleep deprivation experiment. *Soc. Psychol. Pers. Sci.* 2, 166–173
85 Muraven, M. (2010) Building self-control strength: practicing self-control leads to improved self-control performance. *J. Exp. Soc. Psychol.* 46, 465–468