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—Edward R. Hirt

SELF-REGULATION AND EGO CONTROL

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CHAPTER

18

Proximate and Ultimate Causes of Ego Depletion

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INTRODUCTION

Self-regulation is fundamental to long-term success. Although automatic responses correctly guide us through much of our daily lives, these impulses are imperfect and sometimes need to be suppressed or overridden. Most familiar situations have an automatic response or habit attached: when presented with delicious food, you want to eat it; when presented with discomfort, you want to avoid it; when presented with your computer, you want to play games or go on social media. Automatic responses are cognitively quick, efficient, and sometimes beneficial, especially when habits align with future goals (Adriaanse, Kroese, Gillebaart, & De Ridder, 2014; Galla & Duckworth, 2015). However, automatic responses are sometimes misaligned with long-term goals, such as losing weight or finishing school work, and people must self-regulate to inhibit the automatic response and replace it with a different behavior. This act of inhibition requires mental effort (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Kool, McGuire, Rosen, & Botvinick, 2010).

Mental effort, however, appears exhaustible. Mental ability gradually weakens with use of cognitive effort, resulting in temporary fatigue (Hagger, Wood, Stiff, & Chatzisarantis, 2010; Warm, Parasuraman, & Matthews, 2008). Mental fatigue has been extensively documented during prolonged tasks, especially when the tasks are cognitively demanding (Boksem & Tops, 2008; Warm et al., 2008). When a person is asked to do a single task for an extended period of time, they report feeling mentally tired and their performance on the task starts to decrease. Fatigued people make more errors, are less attentive, and are slower to respond (Lorist, Boksem, & Ridderinkhof, 2005; Lorist et al., 2000).

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In vigilance tasks, mental fatigue limits participants' ability or willingness to complete the fatiguing task successfully. However, these fatigue effects are not only due to the monotony of doing a single task (Pattyn, Neyt, Henderickx, & Soetens, 2008)—the deleterious effects of mental fatigue also cross over between tasks, so that fatigue from one effortful act leaves people in an error-prone and less competent state for a second, subsequent task (eg, Webster, Richter, & Kruglanski, 1996). We have known about fatigue spilling over to unrelated tasks for over 100 years. Back in 1904, Carl Seashore commented, "the fatigue through a particular activity also reduces the capacity for such work as is brought about through quite different mental activities" (p. 98). Mental fatigue, including fatigue originating in one task and affecting performance on a second one, is a long-known phenomenon[1].

Given that exerting mental effort generally results in a temporary state of mental fatigue, effortful self-control should also induce mental fatigue and all of its accompanying detriments on subsequent task performance. Indeed, a plethora of studies show that using self-control at Time 1 often reduces performance on various other self-control tasks immediately following at Time 2 (Hagger et al., 2010). This decrease in self-control due to previously using self-control is commonly referred to as *ego depletion* (Baumeister et al., 1998). We consider ego depletion to be a form of mental fatigue, centering on the sequential task paradigm and the use of self-control. It should be noted, however, that not all self-regulation is necessarily fatiguing or depleting. People with high trait self-control may only rarely engage in depleting inhibition, and instead cultivate beneficial, goal-compatible habits (Gillebaart & De Ridder, 2015). People with the right kinds of motivation seem to accomplish their goals effortlessly and are not tempted by goal-inconsistent behaviors (Milyavskaya, Inzlicht, Hope, & Koestner, 2015). Thus, these individuals frequently perform self-regulation without having to actively and effortfully suppress unwanted automatic responses and do not become depleted afterward. Ego depletion seems restricted to situations where the exertion of self-control is perceived as effortful (Clarkson, Hirt, Jia, & Alexander, 2010; Werle, Wansink, & Payne, 2014).

Understanding the causes of ego depletion—and of mental fatigue broadly—can help researchers discover the boundary conditions of fatigue, when it can or cannot be prevented, and ultimately how to encourage self-regulation in society. Not every situation or every experiment results in depletion. Indeed, there are many known moderators of the effect

[1] The phenomenon that we now call ego depletion has long been known, but never undisputed. Edward Thorndike (1900) insisted that previous cognitive work "did not decrease one jot or tittle the ability of the scholars to do [subsequent] mental work" (p. 547).

(Baumeister et al., 1998; Job, Dweck, & Walton, 2010; Tice, Baumeister, Shmueli, & Muraven, 2007) and no doubt additional unknown moderators, some of which may account for situations where depletion is expected but not found (Converse & Deshon, 2009; Dewitte, Bruyneel, & Geyskens, 2009; Xu et al., 2014). Understanding the theory behind depletion can inform our methods to more reliably detect the depletion effect, which has sometimes proved illusive (Carter, Kofler, Forster, & Mccullough, 2015). Improvements of theory, methods, and research practices can improve our grasp of ego depletion and allow researchers to move forward and answer new questions.

Overview

In this chapter, we explore the ultimate and proximate causes of ego depletion, expanding and updating the framework setup by Inzlicht, Schmeichel, and Macrae (2014). The shifting-priorities process model was previously introduced as an alternative explanation of ego depletion, an explanation which does not rely on a limited resource. The model primarily explains *changes* in self-control across time. Why can someone resist unhealthy snacks for a short of time, but then give up and binge after a difficult day at work? Why does one previous activity reduce some people's willingness to perform a second difficult task?

In this extension of the process model, we first ask: from an evolutionary perspective, why are failures of self-control ever permissible? Various lines of evidence suggest that we have two drives: one to satisfy immediate, leisurely urges and one to perform effortful work to prepare for our future. Although we frequently feel that denying immediate pleasure for long-term benefits is the hallmark of success, it is evolutionarily advantageous to ensure that your immediate needs are constantly taken care of (by exploiting known resources), prior to taking care of your future self. Gathering knowledge and resources for the future is important, but only in moderation, as time spent preparing for the future is time that could otherwise be spent on more immediately prosperous activities. We first explain this trade-off in terms of an exploration–exploitation conflict, where we will introduce how the perception of effort accompanies unpleasant delayed gratification. We then parallel the exploration–exploitation trade-off with finding a balance between labor and leisure and discuss ego depletion as the craving for leisure that occurs after an excess of effortful work.

Next, what are the proximate mechanisms of depletion? In the second half of this chapter, we discuss how the labor and leisure balance leads to decisions between have-to and want-to goals, and how construal of any task as effortful or enjoyable is subjective. When an activity requires the use of executive functions (particularly sustained attention and inhibition) and is not perceived as immediately rewarding, it is perceived as effortful and fatiguing. As this effortful task is performed, motivation and attention shift so that reward-related neural areas are additionally activated and control-related areas are less responsive. A depleted person experiences increased approach motivation, an aversion toward additional effort, and a subjective feeling of fatigue. This proposed mechanism for depletion, the shifting-priorities process model, allows for other motivational influences to compensate for depletion and also allows for individual variation in levels of depletion, as depletion relies on the previous task being perceived as effortful by that specific person. Finally, we discuss consequences and predictions of this account and briefly compare the shifting-priorities process model with two other theories of ego depletion.

ULTIMATE CAUSES

First, why is effort aversive, why does it lead to fatigue (Kurzban, 2016)? Evolution is imperfect, and many inefficient or impractical traits will continue to proliferate in a species if not harmful enough to be consistently selected against (Kurzban, Duckworth, Kable, & Myers, 2013), but a trait with negative consequences and no reciprocal benefit is unlikely to survive across thousands of generations. Impaired physical endurance (Dorris, Power, & Kenefick, 2012; Marcora, Staiano, & Manning, 2009; Molden et al., 2012), decision-making (Pocheptsova, Amir, Dhar, & Baumeister, 2008), vigilance, and reaction times are clearly unfavorable in almost all environments and cultures (and for many species), and any mechanism that causes these impairments should be selected against. Yet—even when there is no physical fatigue—both humans and other animals put less effort into tasks when they are mentally tired (eg, Weary, Krebs, Eddyshaw, McGregor, & Horn, 1988). Mental fatigue should thus also have an advantageous purpose, which outweighs the occasional loss in productivity that occurs when fatigued. Instead of fatigue causing an overall decrease in ability (presumably evolutionarily disadvantageous), it may instead cause a reallocation of ability and attention. Fatigue may be the signal to switch tasks, to stop doing an unpleasant future-oriented task and instead engage in an immediately rewarding task. Survival emphasizes meeting your short-term needs; preparing for the future (by fulfilling long-term goals) is a luxury to be engaged in only once your immediate needs are met.

Later, we discuss two broad categories of decisions that are frequently made by animals, both human and nonhuman: between exploration and exploitation, and between labor and leisure. The ability to balance between these broad categories of behaviors should be rewarded by natural selection and, importantly, each individual decision point is dependent on the

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decisions that came previously. Given free ability, people and other animals will sample between exerting future-focused "self-control" options and easier rewarding options. The mechanisms that evolved to monitor the equality between these options—such as the phenomenology of fatigue and effort—may be a source of mental fatigue and ego depletion today.

Exploration and Exploitation

One of the first situations that sets immediate rewards and longer-term goals against each other is when a foraging animal decides whether to exploit or explore. *Exploitation* behaviors take advantage of opportunities that will provide immediate known rewards, while *exploration* prepares the organism for future successes by searching for novel sources of future rewards and reducing uncertainty by gathering information (Cohen, McClure, & Yu, 2007). Exploitation is the more conservative behavior, such as getting food from a familiar source—a human going to a favorite restaurant, or a squirrel foraging nuts from a much-frequented tree. Exploration involves some risk; you may discover a new restaurant or tree that is superior to the familiar one, but you may also be disappointed. The optimal balance between exploitation and exploration is difficult to determine because (1) the risk to benefit ratio of the exploration option is inherently unknown and (2) even the known exploitation option has a degree of uncertainty, since rarely does our environment stay exactly the same across time (Cohen et al., 2007). Given this, it is difficult to know exactly when to switch from one strategy to another.

Regardless, it is necessary to find some balance between exploitation and exploration. Exploring indefinitely does not allow for an animal to gather the benefits from any resource, since they will not keep their attention focused long enough to be productive. Constant exploitation in the same locations is also problematic; the known option may gradually become less desirable relative to other options, particularly if the resource is nonrenewable, and becomes more difficult to exploit as time passes (Kurzban et al., 2013). The longer that you try to find berries on a single bush, the more difficult it becomes since there are fewer and fewer berries. Similarly, when doing a literature search, the longer you spend using the identical key search terms, the less relevant the papers will be that you find. At some point, you are best served to go to a different bush, or try different search terms.

Deciding when to leave a feeding area to explore is easier for animals with a single homogeneous, readily available food source—an approximate solution to the explore–exploit problem is to explore once the current location's resources diminish to the area's average (Hayden, Pearson, & Platt, 2011). Humans, in contrast, evolved with diverse omnivorous diets and are able to eat foods of differing nutritional value and accessibility. Effectively deciding between varied food sources is possibly one of the driving evolutionary selection pressures for developing general self-control—sometimes it is better to spend extra effort to acquire a higher-quality food, instead of eating a more readily available lower-nutrition food. Across 36 nonhuman animal species, breadth of dietary resources is the second strongest predictor of performance on experimental inhibitory self-control tasks, after brain volume (MacLean et al., 2014), and animals that eat food that takes longer to materialize also have better self-regulation (Stevens, Hallinan, & Hauser, 2005). Abandoning one readily available food source in search of alternative higher-yield food might be one origin of self-control, the ability to pursue a long-term goal at the cost of giving up short-term reward.

While regulation between exploration and exploitation may have originally evolved to optimize food gathering, the ability to navigate the exploration–exploitation conflict can be used in any situation requiring balance between short-term rewards and long-term goals. Even animals that are capable of enacting self-control to delay gratification—from humans to monkeys—do not always choose to do so (Evans & Beran, 2007). The individual who always waits or goes searching for better food will starve. Each decision to explore or exploit thus is dependent on previous actions. Repeatedly deciding to explore results in more knowledge about the environment, but it also creates "time-on-task" neural changes that gauge how much time has been spent on the unrewarding activity (Hayden et al., 2011; Lorist et al., 2005). This "time-on-task" monitoring then may be used in calculations to determine when it is time to change tasks, to ensure that the exploit–explore balance is maintained and the current self is not neglected.

Humans have evolved to balance short-term and long-term interests in many domains, including ones without edible stakes. The mechanisms that evolved to weigh options of *now or later*—while taking into account variables such as accessibility, immediate need, reward size, and uncertainty—have a built-in bias toward diversity; sometimes now and sometimes later. To balance the explore/exploit conundrum, people should sometimes, but not always, decide to exert self-control, forgo the benefits in front of them, and explore the world to find other options. According to the exploration/exploitation account, people who have previously engaged in self-control, as in during an ego depletion task, become less likely to engage self-control in the future and instead would prefer to gratify their immediate needs (exploitation)[2].

[2] Earlier versions of the ultimate account of the process model (Inzlicht et al., 2014) suggested that self-control tasks corresponded to exploitation (not exploration). In this revision, we recognize that although the term "exploration" sounds like fun from our human standpoint, from the perspective of a foraging animal it shares more commonalities with delayed gratification and self-control. Exploration and exploitation still do not directly map onto labor and leisure in humans; for example, novelty itself is perceived as rewarding by humans.

Delayed or Immediate Rewards

There are other choices between immediate and delayed rewards, which are not tied to exploring and exploiting. Nonhuman animals plan for the future through performing instinctive behaviors such as storing food. However, animals will always prioritize their current needs over any future planning. There is no use saving food for the winter if you are at risk of starving in the summer. While humans frequently use our overdeveloped prefrontal cortex to plan for the future, we also retain the natural bias toward putting immediate needs first.

Immediate rewards are processed differently and more strongly in the brain than delayed rewards. There is evidence for two different neural systems, one for immediate outcomes and one for other delayed outcomes (McClure, Laibson, Loewenstein, & Cohen, 2004). The midbrain dopaminergic pathways of the limbic system create the motivation for immediate outcomes, for seeking rewards and hedonic pleasure. The response strength in these regions even correlates with individual differences in impulsivity (Hariri et al., 2006). Meanwhile, prefrontal and posterior parietal cortexes respond consistently to time-delayed rewards (McClure et al., 2004). Behaviorally, immediate rewards are generally hyperbolically preferred over delayed future rewards in both humans and other animals, a preference called delay discounting (Cohen et al., 2007; Matta, Gonçalves, & Bizarro, 2012). In most cases, a smaller reward now is chosen over a larger reward later. This bias toward immediate rewards makes choosing immediate gratification feel easy and rewarding, and going against the impulse is effortful. Experiencing discomfort (such as refusing a delicious snack) in exchange for a long-term reward (such as losing weight) goes against this bias toward preferring immediate gratification.

Effort Avoidance

While seeking immediate rewards is neurologically encouraged, engaging in nonrewarding acts of self-control is discouraged through the feeling of effort. Use of executive functions such as inhibition, as well as sustained attention and working memory, often feel subjectively effortful, particularly when there is no accompanying reward (see section *Subjective Effort*). Effort itself, both cognitive and physical, is considered mildly aversive or unpleasant (Kool et al., 2010) and may originate in the negative affect arising when conflicts are detected during cognitive control (Inzlicht, Bartholow, & Hirsh, 2015; Saunders & Inzlicht, 2015). The negative feeling of effort creates a cost for an activity, which the perceived benefits must outweigh for someone to engage in the activity. Additionally, when given the choice between an easy task and a difficult task, we will choose the easy task (assuming that the benefits are equal between the two; Hull, 1943). Organisms generally follow the *law* *of least effort* by avoiding unnecessary use of executive functions (Kool et al., 2010)—the law of least effort is complementary to the preference for immediate rewards. Although humans and nonhuman animals can engage in self-control and delayed gratification, performing them without countervailing rewards tasks is perceived as effortful and aversive.

Labor and Leisure

Another common choice in behaviors involves choosing between doing work and taking a break. Deciding to perform work in exchange for a reward, termed *labor*, involves putting up with the discomfort of effort to get the associated reward (Kool & Botvinick, 2014). Alternatively, you might choose to quit the activity, forego both the reward and the aversive effort, and choose *leisure*. People—and maybe some animals—seem to gravitate toward a balance between labor and leisure (Kool & Botvinick, 2014), paralleling the balance between exploration and exploitation, and the general balance between seeking short-term and long-term rewards. An individual decision to perform the laborious effortful behavior instead of the option to stop and satisfy the immediate needs of avoiding effort is not decided in isolation. The longer that someone spends on one task, the more activated are leisurely goals.

Ego Depletion

The proposed shifting-priorities mechanism ensures a balance between short-term gratification and long-term rewards, and, in so doing, explains the phenomenon of fatigue and ego depletion. A traditional ego depletion paradigm, the sequential task paradigm, involves participants completing one self-control task followed by a second. The self-control tasks that are used are varied and include the Stroop task, solving anagrams, resisting food, suppressing stereotypes, suppressing displays of aggression, among many others. All of these tasks have a few things in common: they require exertion of effort, they are not immediately rewarding, and they are extrinsically motivated. Self-control tasks are aversive and are reported to be difficult or effortful (Hagger et al., 2010). Like mental vigilance tasks, they require heightened executive functioning, generally some type of inhibition. The tasks have only the potential for future rewards, but with the certainty of present costs, including foregoing a current gratification.

Performance on the second self-control task is poorer, and self-control appears to "run out" because it is evolutionarily disadvantageous to spend excessive time on tasks with only future rewards and present costs. We evolved to balance between immediate and delayed rewards, with a preferential bias toward immediately gratifying activities. After the first self-control task, our attention switches toward more leisurely or

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exploitative goals. Just because we can engage in self-control and think of our future selves, does not mean that we should do so to the exclusion of our current desires and needs. The more effort that participants spend on the first task, the more important that it is to equalize the balance between short-term and long-term needs by engaging in immediately rewarding tasks. The feelings of fatigue signal that it is time to change tasks to a more rewarding activity.

Summary of Ultimate Causes

Hedonistic drives and approach motivations necessarily evolved to ensure that organisms take care of their immediate needs. Many complex animals, including humans, have also evolved behaviors to prepare for the future: deciding to wait for a reward that will grow in time, or to engage in an effortful activity that should eventually result in a benefit. These long-term preparations are particularly risky when immediate needs are not already satiated, so long-term preparation behaviors that are not accompanied by immediate benefits (such as effortful self-control behaviors) are perceived as increasingly effortful and unpleasant as they continue to be pursued. Eventually, the future-focused behavior is perceived as so effortful and difficult that the behavior is stopped, and an immediately rewarding action is performed instead. This results in a balance being maintained between short-term and long-term needs, between leisure and labor, or between exploitation and exploration. This "ultimate" cause is one piece of how ego depletion and mental fatigue occur in humans today, but this mechanism of trading-off between the two sets of needs is complicated by additional factors of human cognition. In the next section, we discuss how the construal of goals, subjective perception, and autonomy impact the experience of this labor/leisure trade-off, as well as how this mechanism is reflected in the brain.

PROXIMATE CAUSES

Obligatory and Intrinsic Goals

One way that we may construe our behaviors are as actions that we have to do and actions that we want to do. These two types of drives—referred to as *should* and *wants* (Milkman, Rogers, & Bazerman, 2008) or as have-tos and want-tos (Inzlicht et al., 2014)—are personally subjective and dynamic. Whether an action is a *have-to* or a *want-to* is a combination of the when you receive the reward (now or in the future) and whether it is high effort or low effort. In broad terms, we generally want to do things with immediate rewards or things that require no work at all. We generally feel that we should do things that require work, especially for a delayed benefit. Have-to goals are created out of a sense of obligation, either to others or obligation to oneself, while want-to goals are intrinsically meaningful and rewarding as you perform them. Ultimately, we tend to choose to work toward both have-to and want-to goals (Read, Loewenstein, & Kalyanaraman, 1999) in various proportions. Even perceiving the fulfillment of have-to goals can bias people further toward want-to goals (Tobin, Greenaway, McCulloch, & Crittall, 2015).

To complicate the matter, it is not always clear what goal is a have-to and what is a want-to (Sheldon & Elliot, 1998). People's conscious construal of behaviors is not always obvious and does not always match up with researcher's assumptions. For example, saving money for the future is often assumed to be a have-to goal, something that requires self-control and effort (Baumeister, 2002; Milkman et al., 2008). But there are different reasons why people save money, including as a precaution, to enhance self-esteem, or out of pure-miserliness (Canova, Rattazzi, & Webley, 2005). Someone who remembers their growing bank account at the moment when they choose to save money, instead of spend it, might receive an immediate reward of a sense of satisfaction, safety, accomplishment, or even feeling superior to others. On the other hand, personally selected goals and activities are not always intrinsically enjoyable, and sometimes are perceived to be obligations (Sheldon & Elliot, 1998). Even playing video games, the perfect example of a *want-to*, is occasionally reversed; some gamers report "gaming fatigue" where they feel unmotivated to continue their activities, pushed on only to maintain their identity as a gamer, or to play the games they have already paid for (eg, Fahey, 2012).

In the sequential task paradigm, participants first engage in an obligatory, have-to task that is perceived as difficult (Hagger et al., 2010), unpleasant to perform, and provides no direct sense of reward. After engaging in this have-to task, participants are more interested in engaging in their own leisurely and enjoyable want-to tasks. Instead of being focused on doing work, participants become selectively attentive to pleasurable stimuli like pictures of food (Wagner, Altman, Boswell, Kelley, & Heatherton, 2013) or pictures of objects related to rest (Job, Bernecker, Miketta, & Friese, 2015). When they are then subsequently asked to do an additional cognitive control task, their motivation and attentional biases are mismatched with the task requirements. This results in poorer performance on cognitive tasks (eg, Inzlicht & Gutsell, 2007; Vohs, Baumeister, & Schmeichel, 2012) and more selection of immediate rewards such as food (eg, Baumeister et al., 1998; Werle et al., 2014).

Autonomy

Goals may be perceived as "have-to" or "want-to" goals largely on the basis of perceived autonomy. If someone performs a behavior freely, without

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external pressure, they will feel more intrinsically interested in that action and the behavior will feel less effortful (Ryan & Deci, 1987). When participants are made to feel more autonomous, the initial task feels easier and less fatiguing, so they are more able to engage in self-control subsequently; autonomy manipulations thus significantly moderate ego depletion (Englert & Bertrams, 2015; Moller, Deci, & Ryan, 2006; Muraven, Gagné, & Rosman, 2008). In the reverse scenario, when someone is made to feel explicitly out of control (nonautonomous), their approach motivation and desire to complete their own personal goals increases (Greenaway et al., 2015), paralleling the want-to-seeking motivation of depleted individuals. The role of autonomy and self-determination in depletion is further discussed in Chapter 4.

Perceived (Not Objective) Effort

The critical characteristic that separates fatiguing "have-to" goals from energizing "want-to" goals is whether the activity creates feelings of effort. An activity, such as checking your email, might be simultaneously something that you *have to* do and that you *want to* do. In this case, if you truly want to check your email and enjoy yourself while doing it, then you will not experience it as effortful and it will not cause fatigue. The *want-to* attributes supersedes the *have-to* attributes.

Creation of Subjective Effort

The subjective feeling of effort is dissociable from actual cognitive control and is critical for the creation of fatigue. Some studies find that the degree of depletion is primarily caused by the experience of subjective effort (Christiansen, Cole, & Field, 2012) and can even override whether a participant was originally assigned to a depletion or control condition (Thompson, Sanchez, Wesley, & Reber, 2014). Naccache et al. (2005) reported on a clinical patient with a lesion in the left mediofrontal cortex that encompassed the anterior cingulate cortex (ACC), who experienced no subjective effort even when performing normally on executive control tasks, confirming that phenomenal effort must not necessarily exist whenever inhibition or attention is required. Indeed, the existence of phenomena such as *flow*—times of intense, but enjoyable, concentration on a difficult task (Csikszentmihalyi, 1990)—also shows that not all difficult tasks feel subjectively effortful.

When does something feel effortful? There does seem to be some initial values of phenomenal effort, given constant construal and motivation levels. Subjective effort is differentially experienced for different types of tasks: tasks with high sustained attention are reported to be most effortful, evaluations are moderately effortful, and random action is least effortful (Robinson & Morsella, 2014), and some tasks are more effortful when performed visually or audibly (Szalma et al., 2004). This suggests that some constant cost values are assigned to various executive functions.

When construal of a task changes, however, the feeling of effort changes with it (Laran & Janiszewski, 2011; Deci & Ryan, 1987; Werle et al., 2014). Feelings of effort may be produced when the gained immediate rewards are lower than the standard cost of the executive functions, as balanced by the nucleus accumbens and ACC (Botvinick, Huffstetler, & McGuire, 2009). In other words, the degree of subjective effort may be represented by the following equation:

Objective Demand – Immediate Rewards = Subjective Effort (& Fatigue)

Objectively difficult and demanding activities that are also highly rewarding, such as playing video games (Hoeft, Watson, Kesler, Bettinger, & Reiss, 2008; Koepp et al., 1998), are not perceived as effortful and can thus be performed for hours at a time. An immediate reward does not have to be in the form of food or physical pleasure—feeling compassion for others or succeeding at a competition are similarly rewarding (Fliessbach et al., 2007; Kim et al., 2009). An intrinsically motivated task is perceived as less fatiguing than a have-to task, because the intrinsically motivated task provides immediate feelings of reward. Any task that has immediately perceived rewards—assuming that those rewards are salient—can be effortless. A task that is not immediately enjoyable is then effortful, even if it is rationally deemed to be the best choice for the future.

Subjective Effort Drives Depletion

Particular activities can be construed as either have-to or want-to goals and can be perceived as either effortful or easy. The potentially rewarding characteristics can be either salient or ignored. Research has suggested that the perception of effort, not the objective task characteristics, dictates the levels of depletion. This suggests a motivational account of depletion that is dependent on mental categorization along the continuum of labor (not immediately rewarding) to leisure (rewarding). Critical experiments have manipulated perceptions of Time 1 tasks without changing the actual substance of the task. Laran and Janiszewski (2011) manipulated the construal of a candy-rating task as either fun or obligatory and found that such framing affected participants' self-control. Similarly, Werle et al. (2014) manipulated the framing of physical activity to be considered work (exercise) or fun (scenic walk). The construal of the activity as "work" increased participants' self-reported levels of fatigue, decreased their subjective mood, and resulted in reduced self-control as measured by increased consumption of unhealthy food immediately afterward. In these cases, the external construal of the task likely changed the saliency of different task characteristics—increasing participants' focus on the scenery meant that they found the activity more appealing, compared to participants who focused on the physical exertion.

Self-perceptions of one's own fatigue or energy levels influences subsequent task performance, sometimes overriding the effects of objective previous exertion (see Chapter 10; Clarkson, Hirt, Chapman, & Jia, 2011). A series of experiments have found that falsely believing that an easy task is depleting results in subsequently impaired performance, to the extent that perceptions of exerted effort override the effects of actual exerted effort (Clarkson et al., 2010, 2011). Other research has found that even imagining performing effortful tasks may hurt subsequent task performance when the imagined scenario is realistic and concrete, both temporally and spatially nearby (Macrae et al., 2014).

Additional evidence of the importance of construal comes from work on lay theories of willpower (see Chapter 11; Job et al., 2010). Every person may have their own beliefs about willpower and doing work—while some people believe that work is depleting and fatiguing (a view of limited willpower), some people believe that performing work is energizing and vitalizing (unlimited willpower). Self-reported beliefs in willpower moderate ego depletion as in a self-fulfilling prophecy; people who believe willpower is limited experience depletion more than those who believe in unlimited willpower. Beliefs in unlimited willpower also attenuate self-reported fatigue (Francis, Milyavskaya, & Inzlicht, 2016; Job et al., 2010). Implicit beliefs in willpower can also be experimentally manipulated; priming participants with belief in unlimited willpower increases their self-control and focused attention compared to priming them with limited willpower beliefs (Job et al., 2010; Miller et al., 2012). People with theories of limited willpower—either held or induced—seem to more acutely experience the desire for leisure after effortful labor (Job et al., 2015).

This evidence collectively suggests that one's construal of an action significantly determines the effortfulness and depleting nature of that given activity. This is not surprising, given that basic sensory processes, such as visual and auditory perceptions, are meaningfully influenced by top-down beliefs (Balcetis & Dunning, 2006; Bruner, 1957; Eberhardt, Dasgupta, & Banaszynski, 2003; Gilbert & Sigman, 2007). Preexisting motivations or beliefs impact preconscious processing and what environmental information is available to conscious awareness (Balcetis & Dunning, 2006). If someone expects a task to be fun and enjoyable, they will selectively attend to enjoyable characteristics of the task. If someone expects to feel exhausted and frustrated by a task, they will selectively notice both the difficult aspects of the task and signs that their own internal state is tired. The underlying neural markers of fatigue keep track of fatigue by using this perceived information, not by an objective and static measure of the difficulty of the activity. Perceiving something to be effortful then makes that activity effortful.

Neural Representations of Depletion

The decision to engage in something immediately rewarding or effortful is a computation of values and risk, often done via heuristic short cuts

(Evans & Stanovich, 2013; Inzlicht & Schmeichel, 2013). Critically for the understanding of ego depletion, some of the values involved in the computation change as a function of time-on-task, and specific brain areas become more or less reactive as effort continues to be applied. These neural correlates of mental fatigue and of time-on-task then impact how the outcome of the decision is calculated.

Fatigue Markers

There are converging lines of evidence that the brain monitors fatigue and time-on-task, and that at least some of these neural changes can be observed in depletion paradigms. Both the ACC and the prefrontal cortex are implicated in self-control, and both exhibit less responsiveness with increasing fatigue (Cohen et al., 2007; Kurzban et al., 2013). As a task continues, the ACC becomes progressively less active according to both fMRI BOLD signals (Moeller, Tomasi, Honorio, Volkow, & Goldstein, 2012) and less responsive to errors, as measured by the error-related negativity (Boksem, Meijman, & Loris, 2006; ERN; Lorist et al., 2005), a scalp-recorded electric signal thought to be produced by the ACC in reaction to response conflict (Carter & van Veen, 2007). Diminished ERNs have also been observed in classical ego depletion paradigms, where depleted participants have significantly smaller ERNs in response to errors than control participants (Inzlicht & Gutsell, 2007).

Areas of the prefrontal cortex, also intimately involved in self-control, exhibit reduced BOLD activity during second tasks of the sequential task paradigm (Hedgcock, Vohs, & Rao, 2012; Persson, Welsh, Jonides, & Reuter-Lorenz, 2007), and other measures of engagement such as cortisol levels and pupil diameter also decrease (Hopstaken, van der Linden, Bakker, & Kompier, 2014; Tops, Boksem, Wester, Lorist, & Meijman, 2006). Consistent with our understanding of exploration as a self-control process, frontal areas are also increasingly active when strategically employing exploration instead of exploiting a known source of reward (Cavanagh, Figueroa, Cohen, & Frank, 2012). Lastly, the degree to which the ERN decreases with time-on-task varies as a function of personality traits (Tops & Boksem, 2010), paralleling the findings that some people are more susceptible to depletion effects.

Not only do inhibition-related areas seem to become less responsive as fatigue progresses, but reward-related areas—such as the midbrain and orbitofrontal cortex (OFC)—seem to become increasingly active in response to rewarding stimuli (Heatherton & Wagner, 2012; Wagner et al., 2013). The mesolimbic dopamine pathway is associated with immediate rewards and pleasure, including choosing immediate financial rewards instead of delayed and responding to drug or food cues (McClure et al., 2004; Salamone, Correa, Farrar, & Mingote, 2007). fMRI results have shown increased midbrain activity as fatigue increases and

ACC activity decreases (Moeller et al., 2012), consistent with a balancing account between inhibition and gratification. The OFC, which may monitor the reward value and emotional valence of a situation, also has been observed to have more BOLD activity in depleted participants compared to nondepleted participants (Wagner et al., 2013; also see Chapter 14).

Attention does seem to shift as a result of these changing motivational states. Behaviorally, Schmeichel, Harmon-Jones, and Harmon-Jones (2010) found that depleted individuals were more approach-oriented and had increased attention to reward-relevant stimuli (dollar signs). Vohs et al. (2012) also found that depletion increases the strength of desires (as cited in Wagner et al., 2013), and Job et al. (2015) found that rest-conducive objects were liked more after depletion. Schmeichel presents additional evidence of strengthened impulses in Chapter 6. On the other hand, mental fatigue, and perhaps ego depletion, leads to decreased discrimination between task-relevant and irrelevant stimuli on obligatory self-control tasks (Boksem, Meijman, & Lorist, 2005). Reduced attention toward the experimental demands and more attention to appetitive stimuli may be a primary explanation of reduced performance after the use of self-control.

Dopamine

Depletion and fatigue may reflect changes in dopamine activity or sensitivity, both in areas related to self-control—such as the prefrontal cortex and ACC—and areas involved in reward seeking (Holroyd & Coles, 2002). Experimental and correlational evidence in both humans and rats suggests that dopamine is centrally involved in effort-reward decisions, and that shifting tonic (baseline) levels of dopamine activity can result in changes in self-control behaviors. Rats given dopamine antagonists selectively choose a low-reward/low-effort option (leisure) instead of a high-reward/high-effort action, while rats given dopamine agonists selectively choose the high-effort option (Bardgett, Depenbrock, Downs, & Green, 2009; Salamone, Correa, Farrar, Nunes, & Pardo, 2009). Similarly in humans, artificially decreased dopamine impairs performance at inhibition tasks as well as decreased ACC activity (Luijten et al., 2013), while pharmacologically increased dopamine improves self-control (Nandam et al., 2011). Most applicably, a recent pharmacological study found that increasing dopamine with methylphenidate (Ritalin) eliminates the effect of depletion, and this effect seemed specific to cognitive control instead of due to general increases in alertness (Sripada, Kessler, & Jonides, 2014).

Dopamine has previously been linked to cognitive control and error processing in the ACC; the ERN seems to result from a phasic drop in dopamine, a momentary decrease in the release of dopamine in response to the negative stimuli (Holroyd & Coles, 2002). Interestingly, at the same time that dopamine agonists increase tonic dopamine, they decrease phasic dopamine (Cohen, Braver, & Brown, 2002; Frank & O'Reilly, 2006).

Reducing tonic dopamine with the antagonist haloperidol—which is expected to also increase the phasic spike of dopamine released—weakens the ERN in humans (Zirnheld et al., 2004). The increased phasic dopamine obscures the phasic drop in dopamine that normally results in an ERN. We could speculate, then, that fatigue and depletion, characterized by weakened ERNs and poorer cognitive control, may be partially caused by reduced tonic dopamine in brain areas associated with cognitive control, which in turn reduces sensitivity to phasic drops in dopamine (the proposed source of the ERN).

CONSEQUENCES OF THIS ACCOUNT

Limitless Self-Control?

Often, motivational accounts are taken as a sign that self-control is theoretically limitless. Indeed, in a hypothetical situation where the motivation to perform self-control rose exponentially, to constantly exceed the motivational pressure to engage in leisurely activities, then self-control might continue indefinitely. However, practical limitations make this unlikely to occur in the real world (or even in experimental settings). First, the shift in motivation from have-to to want-to goals is not binary—the desire to seek intrinsically rewarding activities likely continues to increase the longer it is denied, while the feeling of fatigue also increases constantly (eg, linearly across a 4-h task; Wascher et al., 2014). Thus, in situations where the external incentive to engage in self-control remains constant (eg, for air traffic controllers) eventually the motivation toward immediate pleasure will overwhelm even the greatest motivation. Second, the shifts in motivation drive a change in attention away from potential external motivating factors. Even if increasing amounts of money and importance are linked to completing a self-control task, the person will attend less and less to those considerations and be increasingly distracted by their desire to switch tasks to something more intrinsically rewarding. Third, some problems that may sometimes be attributed to ego depletion—such as attention lapses during monotonous vigilance tasks such as truck driving—are exacerbated by problems such as sleepiness (for differentiation from depletion see Vohs, Glass, Maddox, & Markman, 2010) or the task's monotony causing habituation to external signals (Pattyn et al., 2008).

The motivational process account of depletion does not mean that self-control will be limitless in practice, at least not without pharmacological intervention. The shift in motivation toward intrinsically rewarding and leisurely activities likely becomes continuously stronger as it is denied, and "willing" oneself to continue in self-control will still eventually be overcome. However, the shifting-priorities process account also suggests

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that when a given task is perceived as leisurely, intrinsically rewarding, and fun, it will not be depleting. Thus, convincing reconstrual of a given activity may help increase persistence and performance.

Not Enough Effortful Labor? Contrafreeloading

The shifting-priorities process model revolves around maintaining a balance between immediate rewards and future self-control behaviors. Depletion and fatigue occur after an excess of future-oriented self-control behaviors, but what does the opposite phenomena look like? Can excess pleasure or immediate gratification cause increased motivation for engaging in effortful tasks? There are situations where human and nonhuman animals choose the more effortful option, opposing the law of least effort. For example, rats, pigs, and bears sometimes choose to press a lever (perform work) to eat food, instead of eating the identical, freely available food (for review see Inglis, Forkman, & Lazarus, 1997; Osborne, 1977). Monkeys will sometimes repeatedly press a screen to watch a movie, even when the identical movies are freely available (Ogura, 2011). This behavior, called contrafreeloading, goes directly against the principle of effort avoidance.

Even humans sometimes engage in contrafreeloading, preferring to eat snacks that require a button press, reminiscent of Pez candy dispensers, instead of eating a snack from a bowl (Tarte, 1981). The preference for the mildly effortful task seems to be due to the novelty of the activity—and indeed, it has been theorized that contrafreeloading occurs so that animals can gain more information about their environment and their various food sources, which is ultimately an example of exploration future-oriented behaviors (Inglis et al., 1997; Inglis, Langton, Forkman, & Lazarus, 2001). Always taking food from the easily available source would perpetuate the lack of knowledge about alternate sources and might be detrimental to the future self. The pursuit of a balance between exploration and exploitation results in novelty seeking and exploration, even though it requires additional work. Sometimes, a desire for autonomy and control can also override the law of less work, such as when people choose to complete a task manually instead of have a computer do it automatically (Osiurak, Wagner, Djerbi, & Navarro, 2013). Fatigue is more commonly experienced than contrafreeloading, due to our innate bias toward the immediately pleasurable, but there is some evidence that the priority-balancing mechanism is bidirectional.

ALTERNATIVE ACCOUNTS

Other models of ego depletion exist and many have strongly influenced the theory presented here. The field of self-control research is gradually acknowledging the central role that motivation plays in depletion, and others have proposed models based on decision-making and motivational research. Here we briefly discuss two common alternative accounts of ego depletion and the relative strengths of the shifting-priorities process model.

Resource Model

The original, most widely known theory is the resource (or strength) model of self-control. Baumeister et al. (1998) first understood ego depletion as the result of a limited self-control resource that existed in the brain, which all cognitive control tasks drew upon. Once someone performed a previous self-control task, they had less of the resource available for the second self-control task. Although widely appealing and embraced, the original resource model was not compatible with subsequent research that showed how motivational and perceptual factors eliminate or strengthen the depletion effect, as discussed earlier (Inzlicht & Schmeichel, 2012). If self-control relied on a physical resource, then receiving payment (Muraven & Slessareva, 2003), watching videos (Tice et al., 2007), or merely believing in unlimited willpower (Job et al., 2010) should not eliminate the depletion effect. The revised strength model of self-control states that depletion symptoms occur to preemptively ensure that the self-control resource never does run out, and that daily experienced fatigue is mediated by this motivation to conserve the resource (Baumeister, 2014). Given that the physical content of the self-control research has yet to be identified, alternative motivational models that do not rely on a resource may be more useful to lead researchers in creating novel hypotheses and predictions (for additional response, see Inzlicht & Berkman, 2015; Inzlicht et al., 2014).

Opportunity Cost Model and Decision-Making Models

The opportunity cost model, proposed by Kurzban et al. (2013), states that mental effort is an indicator of the opportunity cost of engaging in one's current cognitive task, given that each moment spent on that task is unavailable to be spent on other activities. When the benefits of a given activity no longer outweigh the costs (of forgone activities), then we disengage from that activity in favor of an alternative. Although the opportunity cost model has greatly contributed to other motivational accounts of depletion, a strict benefit–cost calculation cannot account for experimental evidence in the depletion and mental-effort literature. In particular, the explicit comparison between the current task and potentially available alternative tasks seems problematic. For example, people do not always choose to engage in the most "rational" behavior; Kool & Botvinick, 2014 found that participants disproportionally choose an easier

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task when the pay of a laborious task increased, diverging from the predicted outcome of a cost–benefit calculation and suggesting that there is an inherent drive toward leisure regardless of the alternative opportunities available.

Additionally, the opportunity cost model and other decision-making models only partially explain the change in utility over time, particularly across two-task designs. These models state that performance decrements on the second task are due to participants having gradually fulfilled obligations to the researchers; however, failures of self-control due to depletion also seem to happen outside of laboratory experiments (eg, Job et al., 2010; Werle et al., 2014). Decision-making models further explain that performance declines are due to decreasing utility of that activity, but then why is the utility of a second self-control task dependent on one's previous engagement in a prior unrelated self-control task? We think that the shifting-motivation process model better addresses the change in task utility over time, particularly across tasks, and is especially compatible with evidence of neurological and motivational changes that occur as fatigue progresses.

Broader models of self-control and decision-making (eg, Chapters 13 and 19) contribute much to our understanding of when self-control will or will not be engaged in; human behavior is impacted by numerous variables not discussed here. The shifting-priorities model is complementary with these frameworks, and specifically fills a gap by explicitly addressing why the "control capacity" changes after an effortful task, why fatigue occurs.

CONCLUSION

Humans have multiple priorities—we care about our current happiness and pleasure a great deal, but we are also interested in maintaining stability and happiness for the future. Finding the balance between immediate gratification and immediate discomfort for future benefit is a long-experienced problem. The problem occurs when an animal decides between exploiting resource and exploring for information, or when a student decides between a comfortable couch and an uncomfortable study desk. Generally, we have an aversion to work that is effortful and not intrinsically rewarding (*labor* or *have-tos*). It is evolutionarily disadvantageous to spend the majority of your time planning for the future, particularly at the cost of taking care of your current self. Thus, although we can engage in laborious cognitive–control activities when they are deemed appropriate, they are experienced as effortful and gradually lead to fatigue. This fatigue, or depletion, further shifts our motivation away from laborious extrinsically motivated activities and toward things that make us feel good—things that we want to do—to restore the balance.

Whether something is experienced as fatiguing or not, however, depends on whether the activity is truly rewardless. Feeling entertainment, competition, compassion, or interest in an activity makes it rewarding and the use of executive functions is no longer experienced as effortful. Only when an activity is done out of a sense of obligation, without any directly experienced satisfaction, is it fatiguing. Effort is situationally construed, but all of us have perceived limits on how much effort we are willing to exert before it is time for a break. Although there is no biological limit to self-control, the more effort that is experienced and the more fatigue that is builtup, the stronger the urge toward immediately pleasing activities and the more attention is directed toward pleasurable stimuli. Effortful self-control has practical limits in the real world. Effortless self-regulation, good habits, and engaging in difficult but equally rewarding activities, however—those are limitless.

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