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Self-Regulation and Depletion of Limited Resources: Does Self-Control Resemble a Muscle?

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The authors review evidence that self-control may consume a limited resource. Exerting self-control may consume self-control strength, reducing the amount of strength available for subsequent self-control efforts. Coping with stress, regulating negative affect, and resisting temptations require self-control, and after such self-control efforts, subsequent attempts at self-control are more likely to fail. Continuous self-control efforts, such as vigilance, also degrade over time. These decrements in self-control are probably not due to negative moods or learned helplessness produced by the initial self-control attempt. These decrements appear to be specific to behaviors that involve self-control; behaviors that do not require self-control neither consume nor require self-control strength. It is concluded that the executive component of the self—in particular, inhibition—relies on a limited, consumable resource.

To do or not to do: Which requires more effort? In principle, performing almost any behavior should require more exertion than not performing it. Eating a piece of pie, for example, requires various muscular movements of arm, fingers, and jaw. Yet most dieters can attest that refraining from such behaviors can seem more difficult and draining than performing them.

In such cases, refraining from the desired behavior involves more than mere passive inaction: Refraining from behaving requires an act of self-control by which the self alters its own behavioral patterns so as to prevent or inhibit its dominant response. A hungry person would normally respond to desirable food by eating it, and so a dieter requires some internal process to prevent that response. That internal process may require a form of exertion that seems more difficult and strenuous than eating. Indeed, people may sometimes give in and perform forbidden behaviors because they lack whatever strength, energy, or other inner resource that is needed to restrain themselves.

The purpose of the current article is to review evidence pertaining to the idea that self-control operates like a muscle or strength. More precisely, controlling one's own behavior requires the expenditure of some inner, limited resource that is depleted afterward. We propose that people have a limited quantity of resources available for self-control and that various acts of self-control draw on this limited stock. The idea that self-control involves expending a limited resource makes fairly specific predictions, especially with respect to self-control failure. In particular, people should tend to fail at self-control when recent demands and exertions have depleted their resource.

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We begin the present review with a brief explanation of how the concept of self-control would incorporate a limited resource model. Then we consider the central prediction that acts of self-control deplete the resource and hence are followed by impairments in subsequent efforts at self-control. We propose that these impairments are not caused (or mediated) by mood, emotion, or learned helplessness patterns and are specific to self-control. If acts of control deplete the resource until it is replenished, then circumstances that require continuous self-control may also lead to a breakdown in self-control.

Self-Control

Self-control is the exertion of control over the self by the self. That is, self-control occurs when a person (or other organism) attempts to change the way he or she would otherwise think, feel, or behave. Self-control behaviors are designed to maximize the long-term best interests of the individual (Barkley, 1997a; Kanfer & Karoly, 1972; Mischel, 1996). People exert self-control when they follow rules or inhibit immediate desires to delay gratification (Hayes, 1989; Hayes, Gifford, & Ruckstuhl, 1996). Without self-control, the person would carry out the normal, typical, or desired behavior (e.g., would fail to delay gratification or would respond automatically). Self-control involves overriding or inhibiting competing urges, behaviors, or desires (Barkley, 1997a; Baumeister, Heatherton, & Tice, 1994; Shallice & Burgess, 1993). Many behaviors (such as solving math problems) may be difficult and effortful but require minimal overriding or inhibiting of urges, behaviors, desires, or emotions. Hence, not all effortful behaviors are self-control behaviors.

Self-control is also critical to the influential distinction between automatic and controlled processes (e.g., Bargh, 1994; Hasher & Zacks, 1979; Shiffrin & Schneider, 1977). Automatic processes are efficient and rigid, whereas controlled ones are costly (i.e., in terms of effortful consumption of resources) and flexible. Probably the majority of behavior occurs in an automatic fashion (Bargh, Chen, & Burrows, 1996), with minimal active participation by the self, but a very important minority of behavior involves having the

person override these simple responses and effortfully implement a different response. Self-control operations can be understood as a large subset of controlled processes, insofar as the self exerts control over its own responses rather than allowing them to proceed in their normal or automatic fashion.

In particular, we are concerned with the *operate* phase of self-regulation (Carver & Scheier, 1982, 1998). In Carver and Scheier's analysis, the operate phase refers to any sort of action that seeks to reduce (or, in the case of negative standards, increase) discrepancies between a perceived aspect of self and a standard. To operate is thus often to change the self. Because the self already has certain characteristics, which include its forms of thinking, feeling, and behaving, changing the self requires overriding those preexisting patterns and responses of thought, emotion, and behavior. These preexisting patterns are characterized by a certain strength, insofar as some are stronger (and hence more resistant to change) than others (see Hull, 1943). Hence, people may have a personal resource or strength that they draw on to overcome the strength of the habit.

The exact nature of the personal resource needed to overcome the strength of the preexisting patterns is unclear, however. The resource may be unlimited, so that any number of behaviors may be controlled at once. The resource may be limited but not expended in the process of self-control, so that a finite number of behaviors may be controlled at a given time, with no aftereffects from having exerted self-control (similar to attentional focus or working memory). We propose that the resource is limited and partially consumed in the process of self-control: A finite number of behaviors may be controlled, and there is an aftereffect associated with self-control as the available amount of the resource is reduced. The resource needed for self-control is a limited, consumable strength, much like a muscle's ability to work. The current article evaluates the evidence in the literature for that model.

Self-Control Strength

Our own laboratory work has furnished evidence in support of a limited strength model. Muraven, Tice, and Baumeister (1998) showed that when a situation demands two consecutive acts of self-control, performance on the second act is frequently impaired. The impairment is found even if quite different spheres of self-control are involved (e.g., an initial act of stifling or amplifying one's emotional response led to a subsequent reduction in ability to work through pain and fatigue while squeezing a hand grip, and a brief exercise at thought suppression weakened subsequent persistence on unsolvable puzzles). The implication is that many widely different forms of self-control draw on a common resource, or *self-control strength,* which is quite limited and hence can be depleted readily.

The self-control strength model can be reduced to several key assumptions, which provide the basis for several hypotheses. First, self-control strength is necessary for the executive component of the self (i.e., the aspect of self that makes decisions, initiates and interrupts behavior, and otherwise exerts control) to function (Baumeister, 1998). Acts of volition and self-control require strength.

Second, self-control strength is limited, in the sense that a person has finite capacity for self-control: People can override only a finite number of urges at the same time. It is quite possible for the resource to be depleted.

Third, all self-control operations draw on the same resource. Directing one's self-control efforts toward one goal should diminish the resources available for self-control in any other sphere.

Fourth, the success or failure of self-control depends on the person's level of self-control strength (among other factors, such as impulse strength). People who have more strength should be more likely to reach a self-control goal, such as losing 10 pounds, than people who are lower in strength. Hence a depletion of strength may result in breakdown of self-control. Also, tasks that require more self-control are more affected by depletion than tasks that require less self-control. For example, depletion of strength affects a dieter's propensity to eat more than it affects a nondieter simply because dieters are exerting self-control whereas nondieters are not.

Fifth, self-control strength is expended in the process of self-control. Acts of self-control not only require the use of strength but also reduce the amount of strength available for subsequent self-control efforts. In contrast, attentional focus or working memory is also regarded as a limited capacity, but it does not remain depleted after use: In principle, the full measure of working memory becomes available for use as soon as one task is done. In contrast, a strength model entails that the available stock of resources is depleted by exertion and must be replenished before the full measure is available again. It thus resembles a muscle that becomes fatigued by exertion and becomes less able to function.

The decrease in self-control strength is presumably not permanent. People normally regain their lost strength, provided that conditions are favorable. The exertion of self-control should consume resources more quickly than they can be replaced, however, thereby resulting in a net decrease in available resources. If people are unable to replenish their strength because circumstances prevent them from resting, then they may become chronically deficient in resources and hence impaired at self-control.

Although we have presented the limited strength model as if the optimal level of self-control strength is fairly fixed, it is necessary to point out two qualifications. First, there are likely to be substantial individual differences in the basic capacity for self-control. In other words, some people have a larger reservoir than others of self-control strength. Second, in principle it may be possible to increase the size of people's reservoirs over time. If self-control operates like muscular exertion, then exercising self-control may increase strength. Although the short-term effect of exerting self-control may be to deplete and diminish one's capacity, the long-term effect may be the opposite. Frequent exercise of self-control followed by the opportunity for full rest and replenishment may gradually increase the individual's total strength for self-control.

Hypotheses

If the inner resource needed for self-control was specifically known and easy to measure, it would be a straightforward task to evaluate whether that resource rises and falls as the strength model predicts. This is clearly not the case, however: The exact nature of the hypothesized resource is not known. The best one can do at present, therefore, is to generate hypotheses from the assumptions of the strength model and then ascertain whether the existing knowledge about self-control conforms to them.

In particular, the self-control strength model predicts that after one difficult attempt at self-control, subsequent attempts at self-control should be less likely to succeed. Self-control strength is used and consumed any time the self actively initiates, alters, or stifles a response. Because the success of self-control may depend on the amount of resources available to the person, a decrease in strength may result in poorer self-control. Like other limited resource models (such as attention), the strength model predicts that simultaneous attempts at self-control (such as trying to avoid eating while also coping with stress) may lead to poorer self-control overall.

Although we believe that the strength model may help to explain why simultaneous attempts at self-control suffer relative to individual attempts, our review emphasizes how self-control performance declines over time following consecutive attempts at self-control. As we have already noted, this is the crucial difference between limited capacity resource models and limited strength resource models: The strength model predicts that exertion is followed by a deficit, whereas a limited capacity model does not. If self-control does indeed consume a limited strength, then after one act of self-control, subsequent self-control operations (even in other, unrelated spheres) should be less likely to succeed. The first part of our literature review, Aftereffects of Self-Control, focuses on the crucial prediction that self-control is impaired when it follows soon after a previous self-control attempt.

In Alternative Explanations, we review evidence regarding the impact of controlling mood and resisting temptations on subsequent self-control performance. In addition, these literatures shed light on some alternatives to the limited strength model. These include the idea that exerting self-control causes bad moods, which could produce the observed self-control failures. We also evaluate whether the decline in self-control is caused by learned helplessness (Seligman, 1975) by examining the impact of the success or failure of the initial self-control effort on subsequent self-control.

In the section entitled Rest and Self-Control Performance, we consider evidence that continuous self-control efforts suffer over time. Because self-control strength is typically regained more slowly than it is used, continuous self-control (which does not permit rest periods for replenishment) should gradually deplete the resource, resulting in a progressive decline in self-control performance. In addition, we review evidence regarding the gaining of strength through the repeated practice of self-control.

Aftereffects of Self-Control

The first and most important hypothesis generated by the strength model predicts that after an initial self-control effort, subsequent attempts at self-control should be more likely to fail. If self-control operations require the expenditure of some limited resource (analogous to muscular energy), then that resource should be depleted (akin to muscular fatigue) for some period of time until replenishment is possible.

To evaluate this hypothesis, we examine prior research that required people to exert self-control and then subsequently measured self-control in some other sphere. We focus on two major demands that typically require exertion of self-control, namely, coping with stress and dealing with negative, aversive emotions. Insofar as these acts consume the limited strength needed for self-control, they should be followed by decrements in performing other acts of self-control.

Aftereffects of Stress

Exposure to stress may result in poorer self-control performance even after the stress itself has ended. Adapting to stress should consume self-control strength, resulting in poorer subsequent self-control performance (Glass, Singer, & Friedman, 1969).

Coping as inhibition. Coping with stress requires the person to continually monitor threatening stimuli (Cohen, 1978, 1980; Lazarus & Folkman, 1984). Monitoring a stimulus requires inhibition, as the person has to override the general tendency of attention to wander. The need to monitor should be stronger when the threat is unpredictable or uncontrollable. Indeed, a predictable noise requires less vigilance and attentional control than an unpredictable noise (Matthews, Scheier, Bunson, & Carducci, 1989).

Likewise, coping with stress may require inhibiting or altering negative emotions and arousal (Hancock & Warm, 1989; Hockey, 1984; Schönpflug, 1983). For example, individuals who respond to demanding situations by inhibiting their responses tend to report less stress (Derryberry & Rothbart, 1988). Similarly, participants who were better at inhibition (as measured by vagal tone) reported better coping with stressors (Fabes & Eisenberg, 1997). Coping seems to involve processes that demand inhibition, such as blocking sensations, overriding thoughts, and stopping emotions (Pennebaker, 1988; Wegner & Pennebaker, 1993), as well as shifting attention and denial (Eisenberg, Fabes, & Guthrie, 1997). Many items on coping measures (e.g., the Coping Operations Preference Enquiry [Carver, Scheier, & Weintraub, 1989] and the Ways of Coping Questionnaire [Lazarus & Folkman, 1984]) refer to inhibition and overriding (e.g., I just concentrated on what I had to do next; I tried to keep my feelings from interfering with other things too much). In summary, coping with noise or similar stressors requires the person to override or stop thoughts, urges, and emotions, as well as to regulate attention.

Noise. Research on noise has indeed found that after exposure to a stressor, subsequent self-control is poorer. In an important early study of the aftereffects of stress, Glass et al. (1969) exposed people to unpredictable noise or to a less stressful regimen of regular, predictable noise. Afterward, in a quiet setting, the researchers measured performance on proofreading and frustration tolerance tasks. The unpredictable noise led to significant decrements on these subsequent measures.

In the next study, Glass et al. (1969) exposed participants to the unpredictable noise that had yielded the most severe, stressful aftereffects in their first study. Half the participants were told that they could press a button to terminate the noise if they felt they must. They were encouraged not to press the button, and no one actually pressed it. Glass and his colleagues reasoned that feeling able to escape from a demanding situation requires less coping from participants and hence less "psychic energy" (see Corah & Boffa, 1970; and Pervin, 1963, for the relationship between perception of escape and coping). The participants who had the button did not show the subsequent decrements in performance. Thus, the subjective perception that they might be able to control the noise reduced the aftereffects of exposure, possibly because people did not exert as much self-control effort to adapt themselves to the situation.

Glass et al.'s (1969) findings that people perform more poorly following an uncontrollable or unpredictable noise have been replicated many times. The impairments have been found for both random, intermittent noise (Gardner, 1978; Moran & Loeb, 1977) and continuous noise (Hartley, 1973), in both laboratory (Glass & Singer, 1972) and naturalistic settings (Cohen, Evans, Krantz, & Stokols, 1980). The dependent measures of performance have included frustration tolerance (Glass & Singer, 1972; Percival & Loeb, 1980; Rotton, Olszewski, Charleton, & Soler, 1978), proofreading (Gardner, 1978; Glass & Singer, 1972; however, compare with Percival & Loeb, 1980), and the Stroop color–word task (Glass & Singer, 1972). All these tasks involve self-control insofar as the individual must override his or her normal or automatic responses and conform to standards. Uncontrollable and inescapable noise has also been shown to produce decrements on anagram solving (Gatchel, McKinney, & Koebernick, 1977; Hiroto & Seligman, 1975) and concealed figures tests (Krantz & Stone, 1978). Uncontrollable noise also increased subsequent risk taking (Holding, Loeb, & Baker, 1983), an indication of impaired self-control (Leith & Baumeister, 1996).

The degree of control over the noise moderates the subsequent decline in self-control ability. For example, individuals who had the least amount of control showed the greatest subsequent decrements in tolerance for frustration (Sherrod, Hage, Halpern, & Moore, 1977). Similarly, Glass and Singer (1972) showed that the aftereffects of stressful noise were reduced if one had had indirect control over the noise. People who believed that someone else was able to stop the noise for them performed better subsequently than those who believed that the noise could not be controlled. Thus, the belief that it was possible to escape the noise was enough to reduce the aftereffects, again perhaps because people did not exert as much effort to adapt themselves to the situation.

Crowding. Crowding is another potential stressor. As with noise, crowding reduces self-control performance even after the person has been removed from the stressful situation. People who were crowded and who did not have (perceived) control over the situation subsequently showed poorer tolerance for frustration, as compared with people who were not crowded, or as compared with people who believed they had control over the crowded situation (Evans, 1979; Sherrod, 1974).

For example, in the Sherrod (1974) experiment, groups of 8 female high school students performed various tasks in either a small or a large room. After an hour of either relatively crowded or less crowded conditions, all participants were moved into a large area, and their persistence on unsolvable puzzles was measured. Participants who had been in the crowded room did not exert as much effort on the frustrating task as did participants in the control conditions. Sherrod also manipulated perceived control over the conditions by telling participants that they could leave the crowded situation if they wanted to do so, although no one actually made use of this option. Parallel to the noise findings, Sherrod found that perceived control reduced the size of the aftereffects.

Other experimental stressors. Bad odors have been shown to produce performance decrements even after the odors themselves are gone (Rotton, 1983). Participants who believed that they could control a noxious odor by putting a top back on a bottle subsequently worked longer on frustrating, impossible puzzles compared with participants who had no means of controlling the odor.

Glass and Singer (1972) reported that participants were poorer at self-control after exposure to unpleasant electric shock, frustrating experiences dealing with bureaucracy, and being the target of discrimination. For example, individuals who were exposed to an unpredictable and uncontrollable electric shock performed worse on the Stroop and proofreading tasks afterward than individuals who had been exposed to a predictable, controllable shock. In summary, experiences that require adjustment to unpleasant and uncontrollable situations (e.g., not losing one's temper) result in poorer self-control performance subsequently.

General stress. Habits of excessive smoking, drinking, and eating are among the most common, problematic failures of self-control (Baumeister et al., 1994). Coping with stress often leads to relapses of smoking and drinking, as well as diet breaking. For example, coping with stress is frequently associated with relapse in people who are quitting smoking (e.g., Cohen & Lichtenstein, 1990; Wevers, 1988). Longitudinal studies have confirmed that dealing with stress often triggers a relapse—stress at Time 1 predicts relapse at Time 2 (Doherty, Kinnunen, Militello, & Garvey, 1995). Stress has also been found to cause relapses among recovering alcoholics (e.g., Hodgins, el Guebaly, & Armstrong, 1995) and heroin addicts (Marlatt & Gordon, 1980). Dieters are more likely to break their diets following a stressful experience than when they are not stressed (Wadden & Letizia, 1992). In a more direct test of self-control strength and addictions, male social drinkers who had to exert self-control to suppress their thoughts drank more beer and achieved higher blood alcohol concentrations in a situation that called for drinking restraint than social drinkers who did not exert self-control (Muraven, Collins, & Nienhaus, 1999).

We have argued that coping with stress leads to a decreased ability to exert self-control. Alternatively, dealing with stress may cause an increase in the desire or urge to smoke, drink, or eat. Both are possible. Indeed, addictive relapses probably have multiple causes. For instance, Tiffany (1990) theorized that stress might trigger a smoking relapse by putting a strain on the individual's ability to resist automatic smoking behavior, as well as by increasing the urge to smoke.

Thus, various measures and manipulations confirm the general pattern: Exposure to stressful, uncontrollable situations leads to subsequent decrements in self-control even after the stress itself has completely ended (see Cohen, 1980, for a review). This pattern is consistent with the central idea of the strength model, namely, that self-control operations deplete some inner resource that is then unavailable until it is replenished. Adjusting to stressful situations apparently consumes that resource.

Aftereffects of Mood Regulation

Regulating mood and emotional states is another common experience that seems likely to deplete the inner resources required for self-control. Mood regulation requires overriding the ongoing mood and therefore requires inhibition and self-control. Isen (1984) noted that it is common for people to try to bring themselves out of a bad mood, and so even laboratory manipulations of mood induction may often constitute manipulations of self-control. Indeed, individuals behave very differently when they can control their mood than when they cannot, which suggests the crucial factor in many mood manipulations may be the regulation of

mood, rather than the mood itself (Bratslavsky & Baumeister, 1998). Outside the laboratory, it seems fair to assume that people are reluctant to remain in aversive emotional states for long periods of time, and so they have a broad variety of techniques for making themselves feel better (e.g., Thayer, 1996). Hence, people who are dealing with bad moods may be exerting self-control and therefore should show signs of self-control depletion.

Dieting. Dieting requires a great deal of self-control (e.g., Polivy, 1990), and so any depletion of self-control strength should make dieters susceptible to eating more than they normally would. Dieters are more likely to break their diets and eat more than they should after experiencing bad moods (for a review, see Greeno & Wing, 1994). Bad moods and other minor stresses increase dieters' eating, but nondieters do not show any such effect. For example, Baucom and Aiken (1981) manipulated mood by giving people either a solvable or an unsolvable problem and subsequently measured how much they ate. The failure experience led to increased eating among dieters afterwards, as compared with dieters who had succeeded at the puzzle and as compared with nondieters. In fact, failure reduced eating by nondieters. Thus, individuals who are dieting and who experience a negative mood are more likely to lose control over their eating subsequently compared with everyone else. Ruderman (1985), using different measures, replicated these findings. Negative moods induced by failure on an important task (Heatherton, Herman, & Polivy, 1991), by making a speech (Heatherton et al., 1991), and by listening to sad music (Heatherton, Striepe, & Wittenberg, 1998) also lead to subsequent diet breaking.

It is noteworthy that these findings seem to avoid the main interpretive problem we identified with the stress research—namely, that it is difficult to distinguish whether the findings indicate weakened restraints or enhanced impulses. If bad moods lead to stronger urges to eat, then they would presumably do so among both dieters and nondieters, and so eating would increase equally in both groups. In contrast, bad moods seem to increase eating mainly among dieters (who normally strive to restrain their impulses to eat). Assuming that dieters and nondieters are equally likely to regulate their moods by eating (indeed, there is no correlation between emotional eating and restraint; Arnow, Kenardy, & Agras, 1995), the increase in eating in dieters is probably related to a loss of self-control rather than an attempt to alter mood by eating. Previous attempts at self-control undermine self-control performance and do not merely increase the desire to eat. Thus, the alternative hypothesis that dieters eat more when they are in a bad mood as a means of regulating their mood is not well supported.

Resisting other temptations. Emotional distress may lead to breakdowns in spheres of self-control other than dieting. For example, negative affect has also been linked to relapses among individuals trying to quit smoking (Ashton, 1982; Brownell, Marlatt, Lichtenstein, & Wilson, 1986; Marlatt & Gordon, 1985; Shiffman, 1982). Similarly, people trying to stop drinking alcohol report that coping with bad moods triggers their return to drinking (e.g., Hodgins et al., 1995; Pickens, Hatsukami, Spicer, & Svikis, 1985). Addicts trying to kick a heroin habit are also more likely to report relapsing after experiencing a negative mood (Bradley, Phillips, Green, & Gossip, 1989). As with stress, negative moods may lead to an increase in the urge to smoke (i.e., the negative mood increases the desire to smoke), as opposed to weakening inner self-control. Some evidence contradicts this view, however. Drobes, Meier, and Tiffany (1994) had ex-smokers read vignettes about smoking and manipulated negative affect within the vignettes. Negative affect had no effect on participants' urge to smoke (see also Zinser, Baker, Sherman, & Cannon, 1992). Negative moods may undermine people's ability to restrain their smoking behavior leading to a greater chance of relapse (Tiffany, 1990). In short, coping with negative affect may lead to poorer self-control as well as increased urges to smoke.

Delaying gratification. Also consistent with the depletion hypothesis, children in a bad mood are less able to delay gratification compared with children in a neutral or happy mood (Fry, 1975; Mischel, Ebbesen, & Zeiss, 1972; Schwarz & Pollack, 1977; Seemant & Schwarz, 1974). In these studies, children imagined a happy or sad experience and then chose between a small reward now and a larger reward later. Children thinking sad thoughts were more likely to take the small (but immediate) reward as compared with children who were thinking happy or neutral thoughts.

The results of Fry (1975) are particularly noteworthy because this study best demonstrates an aftereffect of dealing with a mood. After children thought about a positive, negative, or neutral event for 30 s, they were told they could play with a toy car but should not play with a mobile. Children who had previously thought about sad events disobeyed instructions and played with the forbidden toy sooner, more often, and longer than did children who had thought about happy or neutral events. The delay of gratification task started after the mood induction task had ended. In other words, the results clearly show that there is an aftereffect for dealing with negative moods, assuming the children had regulated the negative mood away as quickly as possible. Such findings suggest that a strength model is needed to explain self-control, instead of merely a limited capacity model.

In addition, nondepressed people experiencing a sad or angry mood do not delay gratification as well as people experiencing a neutral or happy mood (Knapp & Clark, 1991). Participants read a story that induced either a happy, sad, angry, or neutral mood. They then played a fishing game that required them to delay gratification so that they would not remove too many fish at the beginning of the game. All participants were aware of the need to delay gratification, but participants who had dealt with sad and angry moods were poorer at delaying gratification than were participants who had dealt with happy or neutral moods. The mood had been regulated away by the end of the game, suggesting the inability to delay gratification was caused by a loss of self-control ability and not by a desire to repair a negative mood.

Stamina and thoughts. Some of our own work provides further and direct confirmation that affect regulation can impair subsequent self-control. Muraven et al. (1998) exposed participants to a distressing, sad video clip. Some had been instructed to control and stifle their emotional responses, whereas others had been instructed to amplify and increase their emotions, and participants in a control group were told to not alter their emotional state. Afterward, self-control was measured by persistence on a handgrip task, which requires stamina and resistance to painful fatigue in one's hand muscles. Both groups of participants who had sought to alter their emotional state (i.e., either increasing or decreasing it) showed subsequent decrements in physical endurance on the handgrip, as compared with participants who had seen the same distressing film but who had not tried to alter their emotional state.

Affect regulation was the dependent variable in another study in that same investigation, and the results again supported the strength model. The manipulation in that study was adapted from studies of thought suppression by Wegner, Schneider, Carter, and White (1987): Participants were either instructed to suppress thoughts about a white bear or not. Subsequently, they watched a funny movie with instructions to avoid smiling, laughing, or showing any signs of amusement. Participants who had tried to control their thoughts were subsequently less successful at inhibiting their amusement at the movie, as compared with participants who had not tried to regulate their thoughts (Muraven et al., 1998). Thus, the exercise of controlling one's thoughts apparently reduced some resource that was then unavailable to help individuals control their emotions.

Conclusion

There is extensive evidence to suggest that after one act of self-control, the self-control of other, unrelated behaviors is worse. This is a consistent result across a wide range of studies, including research on stress and emotions that used many different techniques and measurements. Whereas individual studies may have weaknesses, the overall preponderance of studies indicates that there is a reliable aftereffect for self-control. The weakest point in the evidence, perhaps, is the assumption that manipulations of stress and negative emotion do indeed elicit self-control responses. The point of the next section is to examine whether learned helplessness, negative moods, or effort exerted in dealing with the situation can account for the results.

Alternative Explanations

The first section showed that after people deal with stress and negative emotions, they are poorer at self-control, consistent with a strength model. Those same findings might fit some alternative models, however. Stress may generate lasting bad moods that then directly undermine subsequent efforts at self-control. Alternatively, the theory of learned helplessness (Seligman, 1975) predicts that exposure to uncontrollable punishments (such as uncontrollable stresses) or even unsuccessful efforts to alter one's mood might result in the learning of noncontingency between actions and the outcome, so that people learn to not exert self-control. The present section attempts to distinguish between these competing explanations for the decline in self-control after stress and negative affect.

Learned Helplessness

The core idea behind learned helplessness is that a person (or other animal) learns from exposure to an uncontrollable situation that outcomes are not generally contingent on actions (Seligman, 1975). We have already presented evidence that people exposed to uncontrollable stress subsequently tend to fail at self-control. Instead of a depleted capacity, the failure may be caused by learned helplessness, insofar as the person learns from the uncontrollable stress that efforts at self-control are bound to fail. Noncontingency is central to explanations based on learned helplessness. Interpreting the data in terms of learned helplessness would be difficult if initial acts of successful self-control cause subsequent impairments in self-control.

Resisting temptations provides a useful and relevant form of self-control for testing the idea of noncontingency. Resisting temptations requires overriding urges and is a classic, familiar form of self-control. Furthermore, resisting temptations often results in success, as the individual succeeds in not smoking, drinking, or eating. Resisting temptation should confirm the individual's general belief that outcomes are contingent on actions (Marlatt & Gordon, 1985). This section examines whether impairments in self-control follow resisting temptation.

Eating. Consistent with the limited strength model, resisting temptations such as food (when dieting), smoking, drinking alcohol, and taking drugs results in poorer self-control performance. For example, dieting resulted in poorer performance on a vigilance task (Green & Rogers, 1995; Green, Rogers, Elliman, & Gatenby, 1994). Performance on a vigilance task is highly dependent on the ability to control one's focus of attention successfully. Thus, dieting apparently reduces the ability to exert self-control. Green and Rogers (1995) provided evidence that mood or arousal effects cannot account for the impaired vigilance of dieters. Although not all dieting is entirely successful and some temptations are not resisted, it seems excessive to propose that dieting is a training in learned helplessness. Dieters may succeed at resisting temptations in the short term.

Obviously, dieters may be poorer at self-control for reasons unrelated to self-control strength (such as unpleasant moods induced by a restrictive diet). An experimental test of resisting food temptation was conducted in our laboratory to help rule out moods as a potential explanation for these effects (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Participants were deprived of food for several hours and then exposed to the tempting aroma and sight of chocolate chip cookies and chocolate candies. Some were permitted to eat the cookies, whereas others were left alone in the room with instructions to eat only from a bowl of radishes. Covert observations indicated that all these latter participants successfully resisted the temptation to eat the forbidden chocolates. Later, however, they showed decrements in persistence on unsolvable puzzles (Feather, 1961; Glass et al., 1969). We assume that such persistence requires self-control because it involves forcing oneself to continue working (and overriding the desire to quit) despite discouraging, frustrating failure. Participants who ate chocolates and participants in the control condition who were not exposed to food showed no such decrements. No mood differences existed between groups. Thus, resisting temptation led directly to an impairment in subsequent self-control operations.

In a similar series of experiments, Heatherton and Vohs (1997) found that dieters who were presented with tempting food but did not eat it were more likely to break their diet subsequently than dieters who were not presented with tempting food. The temptation manipulation did not affect nondieters, which suggests the crucial factor in these experiments was self-control and overriding temptations, rather than the presentation of the food itself.

Smoking. Smoking cigarettes is another familiar temptation, and efforts by addicted smokers to quit the habit must presumably require considerable self-control that should therefore lead to decrements in other spheres of self-control. Smoking cessation leads to increased eating particularly among individuals who normally try to regulate (restrain) their eating (Spring, Wurtman, Gleason, Wurtman, & Kessler, 1990). Likewise, in experimental studies, smokers who had abstained from smoking for 24 hours ate more

ice cream than did smokers who were free to smoke; these effects were greatest for individuals who scored high in restrained (i.e., highly controlled) eating (Duffy & Hall, 1988). Changes in taste sensitivity and preference do not seem to account for increased eating in smokers abstaining from smoking (Perkins, Epstein, & Pastor, 1990). Similar to the analysis of stress on eating, the greater impact of smoking cessation on dieters than nondieters suggests that smoking cessation specifically affects self-control. If smoking cessation increased the desire to eat, then everyone should eat more, regardless of dieting status.

Conclusion. Successfully resisting temptation leads to impaired self-control of subsequent, unrelated behaviors. Such success would seemingly teach contingency rather than the opposite, so learned helplessness cannot easily explain these findings.

Negative Emotions and Arousal

Can bad moods or negative affect explain the impairment of self-control following an attempt at self-control? Direct measures of emotions and moods contradict such an explanation. For example, one study on vigilance found no difference between dieters and nondieters in either depression or anxiety, yet dieters had more difficulty regulating their attention for the vigilance task (Green & Rogers, 1995). Likewise, individuals who had no control over an aversive event had the same levels of frustration, tension, anger, and depression as individuals who could control the event (Pennebaker, Burnam, Schaeffer, & Harper, 1977). The differential aftereffects of controlled versus uncontrolled stress cannot therefore be readily attributed to emotions.

For example, participants in a study by Mills and Krantz (1979) had to hold one hand in ice water for 4 min. Some participants were told that they could remove their hands from the water sooner than 4 min (high controllability), whereas others believed that they had no choice about when they could remove their hands (low controllability). Regardless of condition, all participants held their hands in the water for the required time. Participants who could not control the stress performed worse on a proofreading task after the stress had ended as compared with participants who had control over the stressor. The two groups did not differ, however, in their self-reported discomfort, pain, or anxiety.

More generally, evidence suggests moods and emotional states do not mediate the link between uncontrollable stress and subsequent self-control performance (Cohen & Spacapan, 1978; Davidson, Hagmann, & Baum, 1990; Glass & Singer, 1972; Wohlwill, Nasar, DeJoy, & Foruzani, 1976). Both self-report and physiological data support the conclusion that mood or arousal is not the cause of the decline in performance after coping with stress (Spacapan & Cohen, 1983). Similarly, Muraven et al. (1998, Experiment 3) found that participants who had to control their thoughts were in the same mood and were equally aroused as participants who did not override their thoughts. Despite the lack of differences in mood, the group that exerted self-control in the first part of the experiment performed more poorly on a subsequent, unrelated test of self-control, as compared with the group that did not exert self-control in the first part of the experiment. These patterns suggest that the aftereffects of self-control are not caused by negative affect.

Mood effects were separated from mood regulation effects by Muraven et al. (1998, Experiment 1) in a study that was described earlier. Self-control was impaired regardless of whether the participants had tried to increase or to stifle emotion, as compared with participants who did not try to alter their emotional state. Thus, only participants who tried to override their natural emotional state (i.e., follow rules and inhibit the prevailing behavior) exhibited subsequent decrements in self-control.

Effort Demands

The limited strength model predicts that self-control strength is needed only by behaviors that require self-control, as opposed to any difficult or effortful task. Consistent with that, participants who worked on a thought suppression exercise subsequently performed more poorly on a test of self-control, as compared with participants who solved math problems (Muraven et al., 1998, Experiment 3). Although participants who solved math problems reported that they exerted as much effort as participants who suppressed their thoughts, solving math problems does not require overriding a response (unlike thought suppression). Further, self-reported effort exerted on the first task did not correlate with subsequent self-control performance. Conversely, participants' performance on a difficult task that did not require self-control was unaffected by an initial task that required self-control (Muraven, 1998). In short, the effects of the depletion of self-control strength are specific to tasks that require self-control, not to all effortful tasks.

Conclusion

The convergence of the findings from studies on mood measurement and studies on resisting temptation permits the tentative conclusion that mood, aversive states, arousal, mental effort, or a belief about an inability to control the world (i.e., learned helplessness) do not cause the impairments of self-control we documented. Thus, models of the aftereffects of self-control that depend on negative emotions or learned helplessness probably cannot account for these findings. Behaviors that are effortful but do not require self-control do not impair self-control, either. In short, the strength model of self-control may be necessary to account for the findings.

Rest and Self-Control Performance

The strength model predicts that continuous exertions of self-control should conform to a pattern of gradually deteriorating performance, just as continued muscular exertion shows a gradual decline in performance. The early part of the exertion depletes the resources to some extent, and so the later efforts occur on the basis of a diminished strength. Furthermore, a strength model suggests that it could be possible to increase strength gradually through exercise, provided the exercise is suitable and is interspersed with periods allowing for recovery.

Continuous Performance

Continuous self-control is needed on many tasks, especially vigilance tasks. Vigilance requires ignoring distractors in the environment, stopping task-irrelevant thoughts, and regulating emotions like arousal and boredom. Individuals who are poorer at self-control should perform worse on tests of vigilance as they

become distracted and miss events. Consistent with this, individuals who are poorer at self-control tend to perform worse on vigilance tests (Barkley, 1997a, 1997b).

Because vigilance requires self-control, the limited strength model predicts that vigilance performance should be poorer later in the experiment (after strength is depleted) than in the beginning. Vigilance performance does deteriorate over time (Davies & Tune, 1969; for a review, see Davies & Parasuraman, 1982). The longer participants concentrate on trying to detect a signal or stimulus, the less accurate they become at detecting it; a meta-analytic review found the effect size of the vigilance decrement to be moderately large (.71; See, Howe, Warm, & Dember, 1995). The vigilance decrement cannot be attributed to participants simply becoming more conservative (e.g., just becoming tired and ceasing to press the button); instead, the decrements reflect less accuracy. The decline in accuracy over time is caused by an increase in distractibility, more task-irrelevant thoughts, and poorer regulation of unpleasant emotions, all of which indicate loss of self-control.

Many theories of the decrements in vigilance have been suggested, including ones based on arousal, expectancies, habituation, and motivation. None have panned out. Parasuraman (1984) concluded that the decrease in performance occurs because "the level of processing resources needed to detect targets cannot be maintained over a prolonged period" (p. 265), which is essentially saying that vigilance depends on a limited strength that becomes depleted with exertion. Hence, a limited, consumable resource model like self-control strength may best explain the vigilance decrement.

Increasing Strength

In addition to the short-term decline in self-control performance after exerting self-control, the self-control strength model predicts that, like a muscle, repeated practice and rest can improve self-control strength in the long term. In a study by Muraven, Baumeister, and Tice (1999), students were assigned to one of three regimens of self-control drills for 2 weeks, including improving posture, regulating moods, and maintaining a diary of eating. These participants showed significant improvements on self-control, as demonstrated by their ability to regulate their physical stamina and squeeze a handgrip longer, as compared with participants who did not practice self-control.

Thus, not only does self-control show short-term fatigue effects like a muscle does, it also shows long-term improvement, just as a muscle gets stronger through exercise. In other words, there is a long-term effect of gaining strength with practice. In the short term, however, self-control demands reduce strength, so even a dieter (who might be well practiced at self-control) who is dealing with stress performs more poorly on a test of self-control than a dieter who is not stressed. Alternatively, these findings may have to do with gaining a sense of self-efficacy by successfully exerting self-control over posture, diet, or mood. The self-control strength model leads to the prediction that people should improve in self-control ability even after failing at the self-control task, however, because the exertion of self-control is more important than the outcome.

Conclusion

These results of vigilance and increasing self-control performance with practice are consistent with the limited strength model of the self. Alternative theories have been largely unsuccessful in explaining the decline in vigilance. The research on gaining strength is new and needs to be replicated before firm conclusions can be drawn. Overall, the results are consistent with the predictions of the limited strength model and inconsistent with other models.

General Discussion

We have reviewed a series of findings relevant to the limited strength model. Although not all results were equally or thoroughly conclusive, the evidence does seem largely consistent with the limited strength model. There is direct support for both main predictions of the limited strength model, namely, that exertion produces short-term fatigue (and hence, subsequent decrements in performance) and that it can lead to improvement or strengthening in the long run. Several alternative explanations have been considered, and the strength model appears to be better able to handle the full range of the evidence than were these alternatives.

Still, it is important not to overstate the findings. Based on present evidence, we conclude that the strength model of self-control operations provides a good fit and may indeed be the best available explanation for the widely assorted findings, but we cannot conclude that it is firmly established as the final, correct explanation. In other words, the strength model may be the leading candidate, but it is premature to declare it the winner. We hope that this review will stimulate researchers to treat self-control depletion as a potentially powerful way of integrating many diverse findings and understanding a broad range of phenomena, but we are decidedly not at the point of recommending that the field consider the case closed or that researchers move on to other questions. Direct tests of self-control depletion hypotheses against competing explanations are warranted. A careful search for boundary and limiting conditions, qualifications, and exceptions promises to yield valuable new insights of the limited strength model.

Summary of Findings

Consistent with the main prediction of the strength model, we found that after an act of self-control, subsequent unrelated self-control operations suffer. After coping with stressors that may require self-control, people's subsequent self-control performance suffers. Coping with stress is also likely to lead to diet breaking and smoking relapses. Similarly, when coping with negative affect and (presumably) trying to make themselves feel better, people are poorer at delaying gratification and other self-control tasks. After resisting temptations, people perform more poorly on tests of vigilance and are less able to resist subsequent temptations (e.g., dieters who quit smoking eat more).

Although uncontrollable stress may trigger feelings of helplessness, we found evidence that self-control performance declines after successful self-control experiences, such as resisting temptation. The success at resisting temptation should constitute reinforcing proof of one's efficacy, and so it should not breed helplessness.

Thus, helplessness cannot account for the decline in self-control performance following an attempt at self-control.

We also found evidence that emotions do not mediate the decline in self-control performance after exerting self-control. Several studies have found no differences in emotion or anxiety between individuals who were exposed to uncontrollable stressors and individuals who were exposed to more controllable versions of the same stressful stimuli. The effects of depletion apparently are not a result of mood or arousal produced by exerting self-control. Also, the amount of effort exerted cannot account for the depletion effects. A task that requires self-control results in a greater decline in subsequent self-control performance than an equally difficult and demanding task that does not require self-control.

Finally, continuing self-control demands gradually deplete the inner resources available for self-control. Performance on tasks that require continual self-control, such as vigilance, is well documented as gradually deteriorating over time, consistent with the strength model. Self-control may also be improved by regular exercise (interspersed with rest). Self-control thus resembles a muscle in more than just fatigue after exertion: It seems able to grow stronger with exercise. This conclusion should be regarded with caution until more evidence becomes available, however.

Motivation and Self-Control Strength

We have suggested that self-control requires a resource that is expended as it is used and must be allowed to replenish by rest. An alternative view, however, is that the decline in self-control under such circumstances simply reflects a drop in motivation to reach a goal. For example, after dealing with stress, people may simply cease to care about keeping their diets or refraining from smoking. Although the motivation and strength models seem at first glance to be competing explanations, it is quite possible that motivation and strength interact to determine the outcome. Recent work on intensity of motivation (Brehm & Self, 1989; Wright, 1996) contends that motivation rises and falls in response to situational factors, such as perceived ability to reach a goal.

People who are lower in strength may desire to reach a goal just as much as people higher in strength. Indeed, it seems likely that people do not want to ruin their diets or start smoking again. The vigilance decrement is found in very highly motivated individuals, such as sentinels in time of war. People's outcome expectancies, or beliefs that if they could exert the necessary effort they would reach the desired goal, should be unaffected by depletion.

A loss of self-control strength may influence the perception of being able to reach a goal, however. In other words, depletion may reduce feelings of self-efficacy (Bandura, 1977, 1997). People who are depleted may feel less able to reach a self-control goal, even if they have performed well on the initial task, perhaps because they are motivated to conserve self-control strength (Muraven, 1998). The motivation to conserve self-control strength may account for the decreased self-efficacy and motivation in depleted individuals. In particular, expending the same amount of strength may be more costly to a depleted person than to a nondepleted person, much as a fixed amount of money is worth more to a poor person than to a rich person (known as the St. Petersburg paradox; see Bernoulli, 1738/1954). Self-control may break down when people are depleted because self-control is perceived to be more difficult and hence depleted individuals feel less efficacious, not because the value of the goal itself has changed.

Changes in the instrumental value of self-control strength may account for another phenomenon as well. People can show effects resembling self-control depletion even when they do not actually experience the self-control demand (e.g., Muraven, 1998; Spacapan & Cohen, 1983). Participants who anticipated future self-control demands such as coping with an uncontrollable stressor or regulating their moods performed more poorly on a self-control task than did people who expected a controllable stressor or did not anticipate regulating their moods. Furthermore, participants who anticipated a future self-control task (either uncontrollable stressor or mood regulation) were no more aroused, anxious, or overwhelmed than participants who anticipated either a controllable stressor or no mood regulation. If people expect to use self-control strength in the future, the instrumental value of the strength increases, thereby reducing people's willingness to use strength in the present. The motivation to conserve strength may therefore lead to a breakdown in self-control.

Unanswered Questions

The analysis presented here is not without its shortcomings, however. In particular, there are several large gaps in present knowledge. Relatively few of the studies reviewed in this article involved direct instructions or requirements for self-control, and so it was necessary to infer and assume that these studies did involve self-control. In particular, the link between coping with stress or dealing with negative emotions and self-control has to be inferred, rather than being based on prior research. We did seek to develop standard and consistent criteria for identifying studies that required self-control, but still, it would be desirable to have more research in which self-control was specifically, directly manipulated (or measured).

Cognitive theories of performance, such as a reduction in attention after exerting self-control, can potentially account for some of the findings we reviewed. Although no formal theory positing a short-term decrease in attentional resources after exerting self-control has been proposed, such a model has been suggested to account for the aftereffects of stress (Cohen & Spacapan, 1978). If the attentional model were accurate, one would expect reaction time (an indicator of attentional resources) to decline after exposure to a self-control demand, whereas the self-control strength model predicts that reaction time should remain the same. Although research has not directly addressed this issue, prior attempts at self-control reduced self-control performance on tasks that seem relatively immune to a decline in attention, such as drinking a bad-tasting beverage (Muraven, 1998, Study 3). Similarly, difficult activities that do require attention, such as solving math problems, do not affect subsequent self-control performance (Muraven et al., 1998). Hence, an attentional explanation does not seem promising for replacing the strength model for all these findings.

The self-control strength model has some features in common with earlier energy models of motivation. For example, Freud's (1957) theory of repression posits a limited pool of mental energy used to repress and control socially inappropriate urges. In some ways, the current model can be viewed as a descendant of Freud's model, as the limited strength model suggests that inhibiting goal-

irrelevant urges and behaviors (that also may be socially inappropriate) depletes people's mental energy. Similarly, Hull's (1943) model of reactive inhibition suggests that repeated responding to a stimulus causes a build-up in inhibition strength (a negative drive with the goal of the cessation of the response that created it), which leads to reduced responding until the organism has time to rest. Hull's model is largely concerned with the learning of new responses, although the model may apply to unlearning or overriding existing behavior as well. There is some question about the transfer of reactive inhibition, however; it is unclear whether responding on one task leads to poorer performance on a subsequent task (cf. Haung & Payne, 1977; McIntyre, Mostoway, Stojak, & Humphries, 1972). Self-control strength may be useful in explaining why responding on some tasks leads to reactive inhibition whereas responding on other tasks does not.

The present findings suggest some leading questions for further research on self-control. The processes that replenish this resource require further study. Furthermore, it seems a high priority to investigate whether the self-control decrements we have documented reflect a genuine, thoroughgoing lack of the necessary resource—or merely an adaptive tendency to conserve the remaining resource after some of it has been depleted. Does stress or affect regulation really consume so much energy that the person becomes fully incapable of resisting temptation, controlling impulses, or persisting in the face of failure? Or, alternatively, do the initial demands simply reduce the resource to the point where the person could continue to engage in self-control but normally avoids doing so, as a way of conserving the remaining resource in case it is needed for responding to some extremely important situation?

Implications

In principle, self-control operations could conform to a variety of mechanisms, such as a skill or a schema, as well as a strength model. The evidence reviewed in this article points toward a strength model. If self-control operated like a schema or other cognitive structure, then an initial act of self-control should facilitate subsequent acts, akin to priming (Bargh & Pietromonaco, 1982; Higgins & King, 1981; Wyer & Srull, 1980). Instead, however, we have found that initial acts of self-control tend to impair subsequent acts. Several implications of these results can be suggested, although we emphasize that the research findings we reviewed are not totally conclusive and that further research should continue to ascertain whether self-control does indeed act like a limited resource.

For understanding self-control, the implications of the strength model are straightforward. The work we reviewed suggests that many seemingly irrelevant acts of self-control draw on the same inner resource, which is normally quite limited. Mischel's (1996) suggestion that the concept of willpower be revived for modern self-control theory is emphatically supported by this review. Although the present work is not in conflict with the important cognitive models of self-control (Carver & Scheier, 1982, 1990; Higgins, 1996), it may be useful to augment those models with a recognition that acts of self-control can take the form of an inner resource striving to overcome the power of some impulse, emotion, desire, habit, or other response.

Undoubtedly, there will also be practical applications relevant to the conclusion that self-control is limited. Psychotherapists may find that their clients' ability to change their maladaptive behavior patterns depends in part on what rival demands on self-control capacity are currently central in their lives. In particular, addiction counselors may find it useful to recognize that addictive and relapse patterns are hardest to overcome when the person is subject to depleted resources—including depletion by factors that seemingly have little or nothing to do with the addiction itself.

Conclusion

Self-control failure is central to many of the personal and social problems that plague modern Western civilization. Nor is this confined to the modern West. Medieval and Confucian concepts of virtue, for example, often featured self-control as a central, underlying theme, and it seems safe to assume that a high level of effective self-control throughout the population would be advantageous to almost any society, whereas widespread failures of self-control can spell trouble in any culture or historical circumstance.

This review has provided some evidence that self-control operates like a limited strength. Such a view may provide insight into one major cause of self-control failure. People have only a limited capacity to control and alter their behavior, and this capacity appears to be vulnerable to depletion in the aftermath of strenuous use. When people find themselves in circumstances that make strong, novel demands for self-control or indeed, when people squander their self-control strength in unproductive endeavors, they may find that their self-control breaks down in other, unrelated spheres. Controlling one's own responses can be costly and draining in the short run, even if it is beneficial, constructive, and adaptive in the long run. More generally, the effective operation and management of limited strength may be one valuable key to understanding how the self functions.

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