

Longitudinal Improvement of Self-Regulation Through Practice: Building Self-Control Strength Through Repeated Exercise

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ABSTRACT. This study examined the results of repeated exercises of self-control in relation to self-regulatory strength over time. A sample of 69 U.S. college students spent 2 weeks doing 1 of 3 self-control exercises: monitoring and improving posture, regulating mood, or monitoring and recording eating. Compared with a no-exercise control group, the participants who performed the self-control exercises showed significant improvement in self-regulatory capacity as measured by quitting faster on a hand-grip exercise task following a thought-suppression exercise.

SELF-REGULATION INVOLVES altering one's own responses (e.g., cognitive processes, feelings, and behaviors). Insofar as self-regulation liberates human behavior from being driven solely by external stimuli and automatic, reflexive, or instinctual responses, it contributes greatly to the diversity and flexibility of human behavior. Thus, the capacity for self-regulation must be counted as one of the most precious endowments of the human self (Baumeister, 1998; Higgins, 1996).

There is evidence confirming the high value placed by psychological theorists on self-regulation (or self-control). In a recent review of the literature, Baumeister, Heatherton, and Tice (1994) concluded that self-regulation failure is a central part of the majority of personal and social problems in modern Western societies. In longitudinal studies, researchers found that 4-year-olds who showed

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a high capacity to delay gratification were more successful, both socially and academically, in high school and college, suggesting that self-regulation is a central and durable feature of personality (Mischel, Shoda, & Peake, 1988; Shoda, Mischel, & Peake, 1990). Wegner and Pennebaker (1993) confirmed the importance of self-regulation for aiding a broad variety of beneficial and adaptive patterns.

The nature of the capacity for self-regulation has resisted elucidation. The contribution of cognitive and attentional factors is well documented (Carver & Scheier, 1981, 1982; Higgins, 1996). Mischel (1996) has proposed that the concept of willpower should be revived because self-regulation requires something akin to energy or strength. Thus, we were concerned with testing whether the capacity for self-regulation can be improved by exercise across time.

Results of our previous studies (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven, Tice, & Baumeister, 1998) and those of Mischel (1996) suggested that some concept of strength or energy is necessary in any final model of self-regulation. A review of the literature on self-regulation failures revealed that many such failures occurred because people have limited resources for self-regulation and these become depleted in a manner akin to a muscle's becoming fatigued (Baumeister & Heatherton, 1996; Baumeister, Heatherton, & Tice, 1994). An examination of evidence pertaining specifically to patterns of fatigue and depletion in self-regulation found that people showed a variety of decrements consistent with a self-regulatory strength model (Muraven & Baumeister, *in press*). These patterns include the facts that (a) coping with stress has after-effects that encompass a variety of self-regulatory breakdowns (e.g., in eating patterns, substance abuse, or emotional control); (b) coping with emotional distress shows similar patterns; and (c) continued exertions of self-control, as in many successive trials on a vigilance task, show consistent patterns of gradual deterioration. Moreover, these effects appear to be limited to self-regulatory exertions, as opposed to pertaining to all sorts of performances.

We conducted a series of studies involving consecutive but seemingly unrelated acts of self-regulation to provide direct evidence that self-regulation operates like a strength. If self-regulation operated like a schema or knowledge structure, performing one act of self-regulation would improve subsequent performance on self-regulation by priming the schema. If self-regulation were a skill, there would be no change, insofar as skill remains constant on consecutive trials. Contrary to the skill and schema models but consistent with a strength model, self-regulation on a second task was consistently impaired by prior exertions of self-regulation (Muraven et al., 1998). Thus, trying to control emotions led to decrements in physical stamina and endurance on a subsequent test, and trying to suppress forbidden thoughts led people to give up more quickly on a subsequent anagram task. Thought suppression also resulted in people's being subsequently less able to inhibit their emotional responses to a video clip. In other research, resisting temptation resulted in people's being quicker to give up on an unsolvable geometric puzzle, and trying to stifle one's emotional respons-

es to funny or sad videos resulted in poorer performance on solvable anagrams (Baumeister et al., 1998). These studies also ruled out various alternative explanations based on mood, expectations, equity, and simple energy. Moreover, in each of these studies, the manipulations and measures were chosen so as to be as seemingly unrelated as possible. The findings suggest that widely different acts of self-control (and perhaps widely different acts of volition in general) draw on one common resource.

These studies support one important aspect of the strength model: fatigue. If the capacity for self-regulation resembles a muscle or strength, then it should grow tired after exertion and perform more poorly immediately afterward.

There is a second prediction made by the strength model. If self-regulation is like a muscle, it should become stronger with exercise. Several traditions of advice from philosophy and folklore support the view that self-control becomes stronger with exercise. Some evidence suggests that alcoholic individuals who are trying to quit drinking may be poorer at regulating their moods, thoughts, and attention in comparison with those not currently trying to break such an addiction, because the repeated efforts of self-control required to resist temptations may consume and deplete the person's self-regulatory capacity (Ludwig & Stark, 1974). However, in the long term, a person who manages to quit drinking alcohol may enjoy an increase in self-regulatory strength from the exercise and hence may be more successful at subsequent undertakings that require self-control, such as quitting smoking (Zimmerman, Warheit, Ulbrich, & Auth, 1990).

Despite such suggestive findings, it is difficult to assemble anything resembling rigorous empirical evidence that self-control can be improved with exercise. Within the confines of the typical laboratory experiment, there is clearly too little opportunity for self-regulation to gain in strength. Indeed, as already noted, we have consistently found that laboratory controlled exertions of self-regulation lead to subsequent decrements, not increments (e.g., Baumeister et al., 1998; Muraven et al., 1998). If exercise can benefit self-control, that benefit should occur after the person has had a chance to recover from the depleting effects of the exertion.

Thus, we used a longitudinal analysis. In two laboratory sessions, separated in time, we conducted the procedures that other research has shown to result in decrements in self-regulatory performance. In between the two sessions, participants practiced exercises designed to increase their self-regulatory strength.

There are at least two basic ways in which our hypothesis about building strength could be confirmed. These correspond to two different ways that muscular strength can be increased: power (an increase in the simple, baseline capacity) and stamina (a reduction in vulnerability to fatigue). We had no a priori basis for predicting which of these we would find, so we tested for both. In the second session, we collected both a baseline measure of self-regulatory capacity and a follow-up measure of self-regulatory performance after a thought-suppression exercise that would deplete the self-regulatory capacity. If exercise increases

strength in the sense of power, then there would be an improvement in the baseline measure from the first session to the second. If exercise increases strength in the sense of reducing vulnerability to fatigue, then the decline from the (baseline) premeasure to the follow-up measure would be reduced at the second session in comparison with the first.

Method

Participants

A total of 69 undergraduate students (42 men and 27 women) participated in our study in return for extra credit in a psychology course. They were mainly White, middle-class American citizens with above-average intellectual aptitudes (as indicated by their attendance at a moderately selective university). They were assigned to one of five groups, and each group was randomly assigned to one condition. Initial instructions, including demonstration and practice, were given to all of the participants at once.

Participants were not told the purpose of the study. They were told only that the project involved an exercise in collecting data about themselves and that they would be doing tasks in a group as well as performing some tasks by themselves outside of class. The importance of the project was stressed. There was no mention of self-control. The laboratory tasks were presented as if they were unrelated to the tasks assigned to be done at home.

Procedure

Session 1. The first meeting featured the initial baseline measure of self-regulation. The measure involved squeezing a hand grip, a procedure that we had developed and validated in previous work (Muraven et al., 1998). The apparatus is a commercially available device used for building physical strength in one's hands. It consists of two handles separated by a spring. The user squeezes the handles together, compressing the spring and creating resistance. Maintaining the grip is tiring for the hand muscles, and eventually it becomes necessary to relax them. Insofar as overriding the urge to relax requires self-regulation, the duration of each participant's grip constitutes a measure of self-regulatory performance. This test is also sensitive to individual differences in physical hand strength; we included before-and-after measures to control for this. To allow a precise determination of when the hand grip was released (because some people may relax their grip only gradually), the experimenter inserted a wad of paper between the two handles when the participant began the exercise, and the paper remained in place only as long as the handles remained fully pressed together. As soon as the paper fell, the experimenter stopped the stopwatch and recorded the time.

To adapt this procedure to the group setting, we had participants pair off and exchange roles as experimenter and participant. Participants timed one another's performance on the hand-grip task.

After the first hand-grip measure, the participants performed a thought-suppression task. They were instructed not to think about a white bear (Wegner, Schneider, Carter, & White, 1987). This was presented as a test of their abilities to ignore thoughts and sensations. The task lasted 5 min. During this time, participants listed their thoughts on paper to ensure their concentration on the assigned task. At the end of 5 min, the experimenter again assessed the participants' self-regulatory capacities by using the hand-grip endurance procedure. Afterward, the participants completed a brief manipulation and procedure check.

Self-control exercise. The experimenter briefed participants on the exercise they were assigned to perform for the next 2 weeks. He emphasized the importance of following the directions and exerting as much effort as possible. When possible, the experimenter who administered these instructions and passed out the materials was different from the one who administered the hand-grip measure. More generally, we were careful to minimize any perception by participants that the hand-grip task and the self-control exercises were related.

Participants in the posture condition were told that they should try to maintain good posture at all times. They were told to sit up straight, to walk erectly, and so forth. They were told to try to improve their posture as often as they could remember to do so. They were also instructed to keep a diary of their progress.

Participants in the mood-regulation condition were instructed to try to improve their moods and emotional states as consistently as possible. They were told that they should regularly strive to change their bad moods into good moods whenever they could. They were instructed to keep a diary of their progress.

Two groups (Food Diary 1 and Food Diary 2) were instructed to maintain diaries of what they ate for 2 weeks. These diaries were considerably more extensive than the diaries required of the posture and mood-regulation participants. The reason for this was that the posture and mood-regulation conditions featured direct exercises in self-regulation, and the diary was simply a record and stimulus. For the food-diary groups, the keeping of the diary was the exercise in self-regulation. (There were no instructions to alter one's eating habits.)

We also included a no-effort control group. This group was not given any instructions or exercises to perform during the intervening 2 weeks.

Session 2. At the end of the 2 weeks, participants returned to the laboratory for the final session. The hand-grip and thought-suppression procedures were performed again (exactly as at Session 1). Afterward, participants filled out a manipulation and procedure check, and the experimenter measured compliance with the instructions during the past 2 weeks.

Results

Manipulation Check

An inspection of the diaries indicated that all of the participants who turned in materials performed the correct exercises. The diaries revealed that some of the participants did more than others. Thirteen participants did not turn in their materials for either week of the procedure, although it seemed likely that they had performed some of the assigned exercises. We decided to retain their data in the main analyses as a conservative procedure, although we conducted separate analyses for them.

Self-Regulation

The main dependent measure was performance on the hand-grip exercise task. Four scores on this measure were available for each participant, corresponding to the four performances (i.e., before and after the thought-suppression exercise and at Sessions 1 and 2). These times were entered into a 5 (practice group) \times 2 (before thought suppression vs. after thought suppression) \times 2 (Session 1 vs. Session 2) analysis of variance, with the latter two variables within subjects. The three-way interaction between practice group, before–after, and session was significant, $F(4, 64) = 2.69, p < .05, d = .72$. No main effects or two-way interactions were significant. The main effect for before–after was also significant, $F(1, 64) = 8.46, p < .01$, indicating a general tendency toward fatigue and depletion. No other effects were significant.

There were two ways that we could have operationalized and measured improved strength. One was an improvement in simple regulatory capacity. This form of improvement would be indicated if the baseline measure improved from Session 1 to Session 2, regardless of the postmeasure. In other words, participants who had performed the regulatory exercises would show an improved capacity to squeeze the hand grip on the first measure (i.e., before the thought suppression task) in comparison with the control group. We analyzed the data for any indication of improvement in the baseline endurance level from Session 1 to Session 2, relative to the control group. We found no such evidence. The baseline scores were approximately stable from the first session to the second.

The other possible form of improvement was a reduced vulnerability to fatigue or depletion. This meant that the drop in hand-grip performance following the thought-suppression task was reduced (i.e., among participants who had performed the regulatory exercises for 2 weeks). The interaction we found suggests that this was what in fact happened. For a more direct test, we computed a regulatory improvement index. For each participant, we computed the change in performance at Session 1 by subtracting the hand-grip duration before the thought-suppression exercise from the hand-grip duration after the thought-

suppression exercise. We did the same for Session 2. We computed the improvement index by subtracting the Session 1 change score from the Session 2 score. The resulting improvement index shows how much better or worse the participant withstood the depleting effects of thought suppression at the end of the 2-week practice period. These scores are found in Table 1.

We entered the improvement index scores into a focused contrast to compare the four groups who had practiced self-regulation with the control group. Participants who practiced self-regulation for 2 weeks differed significantly from the control group, $F(1, 64) = 5.57, p < .025$. Relative to the control group, members of the other four groups showed improvement or a smaller decline in performance following the thought-suppression exercise.

An inspection of the data revealed two noteworthy patterns: The control group showed greater vulnerability at the second session than at the first, presumably because of stresses and other self-regulatory demands extraneous to the study. (The psychology course had its first major test at the time of the second sessions.) It also appears that one of the regulatory exercise conditions was less successful; the mood-regulation group showed results similar to those of the control group (i.e., poorer performances at Session 2).

Effort

It seemed reasonable to expect that all of the participants would not comply with or benefit from the practice exercises equally, assuming that individuals differ in self-regulatory capacity. As a rough measure of compliance, we counted the number of packets of diary materials turned in by each participant. Compliance effort was rated as high for participants who turned in complete packets for both weeks ($n = 31$). Compliance effort was rated as low for participants who turned in materials for only 1 week ($n = 15$). Participants who did not turn in

TABLE 1
Change in Hand-Grip Performance After Thought Suppression (in Seconds)

Group	Session 1	Session 2	Improvement
Posture	-7.4	-0.4	+7.0
Mood	+4.2	-4.4	-8.6
Food Diary 1	-2.2	-3.0	-0.8
Food Diary 2	-18.1	-5.7	+12.4
Control	-4.0	-22.6	-18.6

Note. Session 1 and 2 values are change scores in endurance measured from before to after depletion. Positive numbers indicate longer endurance after depletion. Improvement values are Session 1 subtracted from Session 2 change. Positive numbers suggest improvement or strengthened self-control because of exercise.

packets for either week were rated as no effort ($n = 13$). The control group was omitted from this classification because they did not have any packets of materials to turn in.

If our main hypothesis (that practice at self-regulation leads to improvement in self-regulatory capacity) was correct, then participants who practiced the most would be the ones who benefited the most. We placed participants into the three effort categories and compared each category with the control group to examine the possible role of effort. Consistent with our hypothesis, participants high in compliance effort showed significant improvement relative to the control group, $F(4, 36) = 3.63, p < .05, d = .83$. In contrast, participants who showed no compliance effort did not differ from the control group, $F(4, 18) = 1.80, ns, d = .44$. Likewise, results from the participants who showed low effort did not differ from the control group, $F(4, 20) < 1, ns, d = .24$.

It is possible that participants who did not turn in any packets (and, thus, did not comply with the practice instructions) should have been excluded from the main analyses. It is impossible to test a hypothesis about the effects of practice by including participants who neglected or refused to practice. These participants were retained in the main analyses to provide the most conservative test. Nevertheless, it is noteworthy that our main finding would indeed gain some statistical power if those noncompliant participants were excluded. The three-way interaction between practice group, before–after, and session (excluding those noncompliant participants) was significant, $F(4, 51) = 3.00, p < .05, d = .76$.

Discussion

The main finding to emerge from this investigation was that repeated exercises in self-control led to an improvement over time in the capacity for self-control on tasks that were seemingly unrelated to the exercises. More precisely, we found that exercise made the participants less vulnerable to ego depletion. Our previous research has confirmed that in the short run, exertions of self-control lead to decrements in subsequent self-control. Our current results complement those findings by indicating that the long-term effects of such exercise may be an improvement in self-control. Both of these findings confirm the view that self-control is similar to a muscle (Baumeister et al., 1994; Mischel, 1996). In the short run, exertion makes self-control tired and diminishes its power; in the long run, exercise makes self-control stronger and increases its power.

More precisely, our findings indicate that a longitudinal series of exercises in building self-control can make people less vulnerable to the general tendency for self-control to deteriorate quickly in response to immediate demands. During Session 1, participants showed patterns similar to those observed in previous studies (Baumeister et al., 1998; Muraven et al., 1998): Trying to suppress forbidden thoughts led to a subsequent decrement in self-regulation, as measured by physical endurance. Apparently, the thought-control exercise depleted some cru-

cial inner resource that was then unavailable to help people make themselves keep squeezing the hand grip. After 2 weeks of self-regulation exercises, the negative effect of that same thought-suppression exercise was significantly attenuated. Thus, the inner resource required for both thought-suppression and hand-grip persistence was less readily depleted after the 2-week exercise.

Our findings did not indicate that the simple capacity for self-control improved. The baseline performance on the endurance task did not increase from the first session to the second session as a function of intervening exercises in self-control. Following the muscle analogy, our results did not show that the muscle (i.e., self-control) had any greater power after 2 weeks of exercise, although the results did indicate that it had greater stamina and was less prone to suffer from rapid fatigue after the exercises.

The method we used was designed to ensure that the manipulations and measures were as different as possible. The manipulations involved 2 weeks of either trying to sit up straight and walk with good posture, trying to improve one's mood, or writing down everything one has eaten. There was no obvious or apparent reason why any of those tasks should alter the impact of trying not to think about a white bear, nor is there any simple reason to expect them to change how long a person can squeeze a hand grip. The primary common link between all of these activities was that they all involved the common capacity for self-regulation.

Although we conceived of the four conditions as containing different operationalizations of the same variable (i.e., all four involved a self-regulation exercise regimen), their effects were not necessarily uniform. It is noteworthy that the mood-regulation condition did not result in an improvement in self-regulation: Mood-regulation participants performed like the control group, and they performed slightly worse at the second session than at the first. There are several reasons to suggest that mood regulation may differ from other exercises in self-control, including its greater inherent difficulty. Unlike posture, which can be altered simply by deciding to change and implementing the change, mood must be addressed via indirect, elusive strategies that are often ineffective at producing the desired changes (Baumeister et al., 1994; Thayer, 1996; Wegner & Pennebaker, 1993). It may be the case that struggling, perhaps unsuccessfully, to control one's mood is relatively useless as an exercise for improving one's overall capacity for self-regulation. It may be that people often try to regulate their moods and so the attempts made in this study did not require an expenditure of any additional effort. Nevertheless, we did not predict this finding and do not regard our investigation as a compelling test of differences among self-regulation spheres or regimens, and so we are reluctant to place much interpretive weight on it.

A longitudinal study inevitably sacrifices some of the control and uniformity that a laboratory study offers. Hence, some caution is necessary in interpreting our results. However, there are several features of our study that increase confidence in our findings in comparison with the difficulties and problems that plague many other longitudinal efforts. First, we were able to sustain a 100% rate

of participation (i.e., everyone who completed the initial session also completed the final session) in contrast to the high dropout rate in many other longitudinal studies. This is attributable in part to efforts to keep the people involved as well as to the relatively short (2-week) duration of our study. We were not able to ensure that all the participants fully complied with the instructions throughout the 2 weeks, although all of the participants who took part in the initial briefing and measure attended the final measure and debriefing. This high rate of compliance seems especially important in a study on self-regulation because it seems likely that individual differences in self-control could have strong effects on dropout rates.

Although it was the decision of the participants to comply with the manipulations on their own behest and in their own time and ways, we were able to obtain the measures under controlled laboratory conditions. The uniformity of the measurement sessions in contrast to the presumed diversity and uncontrolled nature of the manipulations should have made the results more uniform across conditions; thus, the obtained differences can be viewed with some confidence. It seems likely that if we had been able to enforce greater consistency among participants in how they followed the instructions for the self-regulatory exercises, the results might have been even stronger.

We did not find that performance on the first (baseline) hand-grip trial improved from Session 1 to Session 2. This result was in contrast to the view that self-regulatory exercise directly increases an individual's power (as opposed to stamina) for self-control. However, it seems likely that there were powerful ceiling effects deriving from physical strength that constrained the hand-grip performance. Self-regulation involves coming as close as one can to one's own personal ceiling. Because the self-regulatory exercises did not increase hand strength, it may be unrealistic to expect the baseline performance to improve from Session 1 to Session 2, and it may be premature to rule out the hypothesis that the simple capacity for self-regulation would improve with exercise.

Caution in interpreting the results is also warranted by the fact that the control group showed greater susceptibility to depletion at Session 2 than at Session 1. One might ideally have wished for a control group to show no change. Nonetheless, this is why control groups are used in research designs (rather than simply assuming that there had been no change). Session 2 took place later in the semester, closer to the stress of midterm examinations, and it is quite plausible that students at that time were suffering the effects of midsemester self-regulatory demands. The fact that two of the four exercise groups actually improved and one remained steady at the second session indicated that exercise helped students resist the normal tendency to be more vulnerable to depletion at the second session.

In addition, caution is necessary in generalizing from the present procedures to self-regulation and self-control in daily life. We measured self-control under controlled laboratory circumstances in the presence of an experimenter. In everyday life, people must often exert self-control by themselves and without the

supervision of an authority figure. Although the authority of the experimenter in our study was diminished by assigning participants to supervise one another, participants knew they were being studied. It would be desirable to find converging evidence to corroborate our results, preferably in situations in which no experimenter was present.

The suggestion that exercise can gradually improve self-control helps put previous findings of regulatory depletion in context. One potential interpretation of those previous results, which we would not endorse, is that people should avoid exerting self-control because such acts deplete the limited resource. Our findings lend themselves to a more optimistic, socially desirable message: It is good to exert self-control on a regular basis because in the long run, these exercises will strengthen self-control and make a person less susceptible to the depleting effects of a single exertion.

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