

Increasing Self-Regulatory Energy Using an Internet-Based Training Application Delivered by Smartphone Technology

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Abstract

Self-control resources can be defined in terms of “energy.” Repeated attempts to override desires and impulses can result in a state of reduced self-control energy termed “ego depletion” leading to a reduced capacity to regulate future self-control behaviors effectively. Regular practice or “training” on self-control tasks may improve an individual’s capacity to overcome ego depletion effectively. The current research tested the effectiveness of training using a novel Internet-based smartphone application to improve self-control and reduce ego depletion. In two experiments, participants were randomly assigned to either an experimental group, which received a daily program of self-control training using a modified Stroop-task Internet-based application delivered via smartphone to participants over a 4-week period, or a no-training control group. Participants assigned to the experimental group performed significantly better on post-training laboratory self-control tasks relative to participants in the control group. Findings support the hypothesized training effect on self-control and highlight the effectiveness of a novel Internet-based application delivered by smartphone as a practical means to administer and monitor a self-control training program. The smartphone training application has considerable advantages over other means to train self-control adopted in previous studies in that it has increased ecological validity and enables effective monitoring of compliance with the training program.

Introduction

THE ABILITY TO OVERRIDE personal desires, urges, and impulses successfully has been shown to be adaptive and enables individuals to avoid undesirable outcomes such as obesity, alcoholism, and social problems. Attempts to override these behaviors rely on *good* self-control. Promoting good self-control has been shown to have demonstrable benefits such as better academic achievement and interpersonal skills and higher self-esteem.¹

Baumeister et al.² have proposed a strength or “energy” model in which self-control is conceptualized as a limited resource. Research on the model suggests that capacity on actions and tasks that require self-control is determined by the resource that becomes depleted after repetitive acts of self-control. This depleted state results in a weakened ability to resist further self-regulatory demands.² The state of depleted self-control strength or energy has been termed “ego depletion.”³ Self-control is therefore considered analogous to a muscle that has sufficient strength to perform tasks but be-

comes fatigued after a period of exertion. Consistent with this analogy, the ego depletion effect can be attenuated by repeated practice or “training” on self-control tasks, just as a muscle can be trained to become stronger.^{2,3}

The depletion effect is typically tested using a *dual-task* paradigm, an experimental procedure where experimental condition participants are required to engage in two separate consecutive self-control tasks but only the second task requires self-control in the control condition. The strength model predicts that performance on the second task will be impaired for those in the experimental group in comparison to those in the control condition. This is because the first task has used up self-control resources leaving less available for the second task.⁴ Hagger et al. conducted a meta-analysis of 83 studies with 198 tests of the ego depletion effect using the dual-task paradigm. Results revealed a significant medium-sized effect self-control resource depletion on task performance across studies and in multiple domains of self-control.⁵

The present research builds on previous research demonstrating that regular discrete bouts of practice or “training” on

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self-control tasks over a period of weeks or months improve post-depletion self-control performance. For example, research has demonstrated that a program of discrete acts of self-regulation such as controlling language, using a non-dominant hand, posture control, keeping a diary, and even using a strong “mouthwash” repeated daily over a sustained period (e.g., 2 weeks) improved performance on self-control tasks.^{6–9} This research has been corroborated in more “ecologically valid” contexts by Oaten and Cheng^{10,11} who required participants to engage in program of everyday regulatory behaviors (e.g., regular self-monitoring of personal finances, a program of physical activity) designed to increase self-control strength. Participants enrolled in the training program displayed significant improvements in self-control performance on follow-up laboratory self-control tasks and other self-reported regulatory behaviors (e.g., smoking, diet) relative to performance prior to the training regimen. Previous research has included the use of computer-based tasks to train self-control on appetitive and alcohol behaviors successfully.^{12–14} Further, performance on a personal computer (PC)-administered Stroop¹⁵ response inhibition task was used to predict binge drinking behavior and as a PC-based self-control training tool.^{9,16,17} To date there have been no interventions that use the smartphone applications to train self-control.

Overview of Current Research

Rather than using PC-based means to deliver self-control training, the present research adopted a novel means to deliver a self-control training regimen by exploiting the ubiquity and social pervasiveness of smartphone technology to test the training hypothesis. It is estimated that 81% of all UK smartphone users have their device constantly switched on, even when sleeping.¹⁸ Capitalizing on this and recent evidence that a substantial proportion of the UK population (two fifths) currently own a smartphone and that smartphone users are increasingly moving away from traditional means of accessing the Internet such as PCs,^{19,20} we planned to exploit this increased accessibility to administer a program of training to improve self-control. The research aimed to test the efficacy of an Internet-based self-control training intervention delivered by smartphone technology on self-control resource capacity on laboratory-based tasks. The research is novel and innovative in self-control research, as it adopts an Internet-based smartphone training application that offers numerous advantages over traditional means to deliver self-control training. For example, it allows strict control over the delivery of the training in real time and provides a means to validate participant compliance with the training protocol because each user trial is recorded directly by the smartphone and uploaded to a university server. In addition, the smartphone and linked server system provides the facility to “push” requests to engage in a task at any time, allows effective storage of data through an immediate uplink of participant responses to the project server, and negates the need for multiple devices (e.g., an additional pager). Further, any task-generated data are better protected because no data are stored directly on the phone and are instead saved on password-protected servers. This also overcomes the risk of losing data if the device is lost or stolen and maximizes data confidentiality. The use of the current technology has the advantage of pro-

viding a more effective means to evaluate compliance with the self-control training program. Previous training studies have largely relied on self-report as a means to evaluate compliance, while the system presented here overcomes this problem by logging each trial and uploading the data to a remote server via the Internet.

We report on two experiments that aimed to examine the effect of regular discrete bouts of training on a response inhibition task on post-training self-control depletion using our novel Internet-based application to train self-control delivered via smartphone technology. In both experiments, participants randomly allocated to a “self-control” training group engaged in 4 weeks of self-regulation training, while participants allocated to a no-training control group received no training. In both experiments, it was hypothesized that training would improve self-control strength, and it was expected that participants in the training group would perform significantly better on self-control tasks in a dual-task paradigm administered post-training compared to participants in the no-training group after controlling for baseline self-control performance. The experiments adopted identical designs with the exception that the depleting task used in the dual-task experiments across the two experiments was varied in order to provide two tests of the effect and to evaluate its generality.

Method

Participants

University students and staff members (study 1: $n = 29$, 24 female; study 2: $n = 33$, 16 female) agreed to participate in the research in return for £20 of shopping vouchers. Participants were randomly allocated to either a self-control training condition or no-training group.

Procedure

Modified dual-task paradigm. The effectiveness of the training program was established through comparison of the self-control task performance of participants engaging in a dual-task paradigm before and after the training program. Participants were required to engage in two separate consecutive self-control tasks. On arrival at the laboratory, a female researcher greeted participants and asked them to read the study information sheet and sign a consent form. Participants received an initial depleting self-control task (Study 1: a Stroop color-naming task; Study 2: a complex counting task) followed by a second self-control task (handgrip strength task for both studies). For the Stroop task, participants engaged in seven trial blocks (approximately 10 minutes in duration) of Stroop items (238 color words in total) performed on a 15-inch LCD computer screen with an achromatic gray background. Response time for each item was recorded. Each trial block comprised of 34 color words with a ratio of 25% congruent (e.g., the word RED written in RED-colored ink) to 75% incongruent (e.g., the word RED written in YELLOW-colored ink) color word stimuli. Each color word item was presented for a period of 2,000 milliseconds with feedback duration of 800 milliseconds. Color word response options were presented in a vertical list directly below the current color word, selected by the participant using a computer mouse. The complex coordination counting task required participants to

count backwards from 1,000 in multiples of seven while standing on one leg. Managing the complex counting and coordination components of the task requires considerable self-control.^{21,22} The handgrip involved participants holding a commercially available handgrip device for as long as possible. A coin was placed between the handles of the grip when timing commenced and ceased when the coin dropped.^{23,24} A baseline handgrip measure was taken at the beginning of the study to correct for baseline strength. Time spent on this task, corrected for baseline grip strength, constituted our dependent measure of self-control, and a comparison of pre- and post-training values for the training and control groups was made to test the efficacy of the self-control training in allaying ego depletion.

In study 1, we also compared pre- and post-training Stroop response latency values to illustrate improvements in the Stroop task over time. To rule out unequivocally the possibility that any improvements in self-control performance were due to learning effects, in study 2, we instead replaced the Stroop with a complex counting self-control task because it was in a different domain and independent of the training task.

Training tasks. The intervention group engaged in 4 weeks of self-control training using a novel smartphone application, while the nonintervention group did not engage in any training. The training task was based on the Stroop paradigm¹⁵ precisely as described previously in the ego-depleting task using the same computer application. The system was designed to deploy to both a personal computer and a smartphone. The task type was chosen because it is a frequently used depleting task and requires effortful self-control.⁵

Intervention participants engaged in a self-control training program using an Internet-based application delivered by smartphone. The application was Internet-based rather than a native smartphone application in order to avoid constraining our participant group to a particular operating system (e.g., iPhone, Android, Windows, etc.). Prior to deployment, the application was tested across a range of platforms and on a range of touch screen smartphones (e.g., Samsung™, HTC™, Blackberry™, iPhone™). In all but three cases, participants used their own touch-screen smartphone. Nexus One Android™ touchscreen smartphones were provided to the remaining three participants.

A linked server was programmed to send three daily task text messages to each participant's smartphone at predefined times of 8:00am, 1:00pm, and 5:00pm, 7 days per week for 4 weeks. To measure compliance levels, any task that was not performed before a new task came through was deactivated and logged as "missed." A full description of the application can be found in Appendix A.

Follow-up tasks and measures. All participants were contacted by e-mail or telephone and invited to return to the laboratory after 4 weeks. All participants returned, and they received an identical series of tasks as administered in the first laboratory session for comparison to the initial baseline measures. Participants were then asked to complete a trait self-control questionnaire to control for the effect of individual differences in self-control task performance.¹ Finally,

participants were debriefed and thanked for participating in the study.

Results

In study 1, a one-way ANCOVA was conducted to test for the effects of the intervention on self-control strength, with intervention condition (training vs. no training) as the independent variable and post-training Stroop response latency (in milliseconds) as the dependent variable. The covariates were the baseline Stroop response latency scores and trait self-control. Participants who completed the training intervention were significantly quicker ($M=725.39$ milliseconds, $SD=207.06$) on the post-training Stroop trials than those who did not engage in any self-regulation training ($M=985.22$, $SD=197.26$; $F(1, 26)=10.84$, $p=0.003$, $\eta_p^2=0.294$). There was no effect of trait self-control on post-training Stroop response time.

The difference in handgrip duration between the initial and post-depletion handgrip tasks for the dual-task pre- and post-training laboratory sessions was calculated and the values used as the baseline and follow-up dependent measures of ego depletion respectively. A one-way ANCOVA was conducted to test for the effects of the intervention on self-control strength, with intervention condition (training vs. no training) as the independent variable and post-training baseline-corrected handgrip depletion score in the dual-task paradigm as the dependent variable. The covariates were the follow-up handgrip depletion score and trait self-control. To correct for the violations of the assumptions of normality, a log transformation of the handgrip values was conducted.^a Participants who completed the training intervention spent significantly longer (study 1: $M=+4.39$ seconds, $SD=47.85$; study 2: $M=+9.07$ seconds, $SD=31.63$) on the handgrip task than those who did not engage in any self-regulation training (study 1: $M=-24.26$ seconds, $SD=39.65$, $F(1, 25)=6.11$, $p<0.02$, $\eta_p^2=0.196$; study 2: $M=-32.46$ seconds, $SD=21.45$, $F(1, 30)=15.09$, $p<0.001$, $\eta_p^2=0.335$). There was also a significant but independent effect of trait self-control in study 1 ($F(1, 25)=5.40$, $p<0.05$, $\eta_p^2=0.178$) but not in study 2.

Across the 4-week intervention period, overall intervention task compliance was high (study 1: 72.78%; study 2: 83.56%), and the mean percentage color word items correctly answered was very high (study 1: 98.10%; study 2: 96.16%). The mean percentage of color word items answered was very high (study 1: 99.77%; study 2: 96.83%). These results indicate that participants were actively rather than passively engaging with the study tasks.

Discussion

The aim of this study was to explore the efficacy of using an Internet-based application delivered by smartphone to test the hypothesis that training on self-control tasks might improve an individuals' self-regulatory capacity based on the strength model of self-control. The results of this study support the training hypothesis derived from the strength model such that regular discrete bouts of self-control training over a period of weeks can improve self-control capacity and allay the deleterious effects of ego depletion on task performance. The findings add to the growing number of studies that have demonstrated improvements in self-control after a period of training on tasks and activities requiring self-control such as financial monitoring, physical exercise, improving posture,

controlling language, rinsing with a nasty mouthwash, and using the nondominant hand for everyday activities.^{6,7,9,10,11}

The present research specifically wanted to explore the efficacy of using a novel application delivered by smartphone to train self-control. It was found that, overall, pervasive technology such as the smartphone is very useful not only to deliver self-control training programs but also to measure performance and compliance levels accurately in real time. The compliance data provided strong evidence that participants not only adhered to the training protocol but also actively engaged in the self-control training tasks. To date, we are not aware of any other study that has provided objective measures of compliance with the training tasks without the requirement of regular visits to the laboratory. The majority of studies have relied on participant self-reports of compliance that has the potential to introduce additional error variance due to response bias. Regular visits to a laboratory for people to complete the training tasks (e.g., Hui et al., 2009) ensure participants comply with the training tasks,⁹ but also presents problems with inconvenience and therefore the practical applicability of the training program and a possible confound of the training task with the visit itself.⁹ The current smartphone application gets around these problems by providing objective data on compliance through the logging of usage data, and has implications for the design and content of future interventions. Additionally, this method is an important step forward in providing a practical and widely accessible means to train self-control and test the training hypothesis in the context of the strength model.

Current research highlights the efficacy of using smartphone technology as an effective training intervention tool and provides a novel way of testing the training hypothesis. Importantly, the system designed to capture data in real time extends the scope of information that can be assessed in these types of interventions by providing the researcher “at a glance” observation of dynamic changes in behavior over time, and enabling the researcher to intercept and change the intervention protocol as and when required (e.g., provide more difficult Stroop tasks to provide more challenging training for participants as they improve their self-control). The technology-driven training, and the fine-grained data it

generates, also overcomes the reliance on participant self-report frequently used in similar interventions.

Strengths, Limitations, and Future Directions

Strengths of the current research include the adoption of a rigorous experimental design with strict randomization to conditions, use of objective laboratory-based measures of self-control behavior validated in previous research, the adoption of a novel Internet-based training application delivered by smartphone to train self-control capacity, and the use of self-control tasks in different domains as the dependent and the depleting (in Study 2) self-control task demonstrating the transferability of the training effect to tasks in other domains of self-control. Overall, the current research is innovative and contributes to knowledge because it demonstrates the effectiveness of an Internet-delivered training application in producing increases in post-depletion self-control strength using separate tasks to induce ego depletion.

A limitation of the research, though, was its small sample size and the lack of nonlaboratory-based measures of self-control-related behaviors such as that provided by Houben et al. and Oaten and Cheng.^{10–14} Although the study was adequately powered to find significant effects, the studies need to be replicated on a larger sample and to include a measure of changes in other everyday self-control behaviors outside the laboratory such as alcohol consumption; consumption of high-calorie, energy dense foods; amount of physical activity; time spent studying; and extent of impulsive buying. In line with Hui et al.,⁹ the research would also benefit from including a “weak” training group to rule out any potential for attending regularly to the smartphone to affect results and to provide further robust tests of the training hypothesis. Our future work will focus on exploring the optimum task intensity and frequency on the training effects and the lingering effects of the training in order to develop interventions that focus on “maintenance” training at set points. Equally, it is anticipated that the results of these studies will help reduce the challenge of designing training interventions that are effective in a nonlaboratory setting. In addition, future research should consider developing more



FIG. 1. Sequence protocol of Stroop task deployment.

engaging, inherently interesting tasks (e.g., “games” with a self-control training element) to offset concerns of boredom with the Stroop task over extended periods to train self-control, and should exploit such methods of intervention in a range of applied domains.

Notes

a. The analysis was repeated using log-transformed data and the pattern was identical therefore only untransformed scores are reported.

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Author Disclosure Statement

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(Appendix follows →)

Appendix

Appendix A: Sequence Protocol for the Internet-Based Stroop Application Delivered by Smartphone

A bespoke Internet-based smartphone application was developed as a means to deliver a self-control training intervention to participants. A linked web server was programmed to send a text message to each participant's mobile phone. It was programmed to send three daily Stroop response inhibition training tasks at predefined times of 8:00am, 1:00pm, and 5:00pm, 7 days per week for 4 weeks with a manual override in contingency for network or server failures. The manual deployment application was uploaded onto a separate smartphone (Android™ OS) and stayed with the study researcher for the duration of the study. The study tasks were based on the Stroop paradigm²⁵ and were proposed to tax response inhibition such that the participant has to resist the urge to name a target word instead of the ink color in which it is written. This type of task is frequently used as both a depleting and dependent task in studies using the dual-task paradigm and, as such, is an ideal task type to practice self-control.⁵ Each deployed task remained active until another task was deployed. The benefits of deactivating previous tasks on deployment of a new task provided the opportunity to measure compliance levels. The task deployment procedure is detailed below. Screen shots of the sequence of the Stroop task deployment protocol can be seen in Figure 1.

Step 1. A text message containing a unique URL link was sent to the participants' phone. The participant was asked to

open the text message and click on the embedded link. The URL link directed to a Web site and a welcome screen that provided the task instructions.

Step 2. After reading instructions, the participant was required to press a "Start Task" button on the welcome screen to commence the modified Stroop color naming task. A series of color word (red, blue, or green) items (34 per task; 75% incongruent and 25% congruent) were presented consecutively on the screen. The participant was required to make his or her color response by pressing the relevant color button on the touch screen until all items were completed. The response time for each individual color word item was recorded by the device then uploaded immediately at the end of each task to a linked server and logged. A 30-second time allowance was provided for the participant to respond to each color word item after which the response was logged as "unanswered" and the next color word item was presented. Importantly, the response time is logged by the phone rather than the Web site so there is no delay or misrepresentation of response time.

Step 3. Participants were informed on the screen once the task had been completed along with instructions on how to exit the application. If a Stroop task prompted by a text message was not completed before a next scheduled one is deployed, it was logged as "missed" by the server and the participant was not be able to return to the missed task via the URL link.