



## **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 effectively regulate future behaviors that require self-control. 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 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 four-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 a novel Internet-based application delivered by mobile phone 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.

**Keywords:** regulatory control; inhibitory training; ego depletion; smartphone technology

### Introduction

The ability to successfully override personal desires, urges, and impulses 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.<sup>1</sup>

Baumeister and colleagues<sup>2</sup> have proposed a strength or ‘energy’ model in which self-control is conceptualised 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 resulting in a weakened ability to resist further self-regulatory demands.<sup>2</sup> The state of depleted self-control strength or energy has been termed ‘ego depletion’.<sup>3</sup> Self-control is, therefore, considered analogous to a muscle that has sufficient strength to perform tasks but becomes 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.<sup>2,3</sup>

The depletion effect is typically tested using a *dual-task paradigm*, an experimental procedure in which participants assigned to an experimental condition are required to engage in two separate consecutive self-control tasks while participants assigned to a control condition also receive two tasks but only the second requires self-control. 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 depletes self-control resources leaving less available for the second task.<sup>4</sup> A meta-analysis of 83 studies with 198 tests of the ego depletion effect using the dual-task paradigm revealed a

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significant, medium-sized effect of self-control resource depletion on task performance across studies across multiple domains of self-control.<sup>5</sup>

The present research builds on previous research demonstrating that regular discrete bouts of practice or ‘training’ on 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., two weeks) improved performance on self-control tasks.<sup>6,7,8,9</sup> This research has been corroborated in more ‘ecologically valid’ contexts by Oaten and Cheng<sup>10,11</sup> 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.

### **Overview of Current Research**

In the present research we adopt 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 of the strength model of self-control. We plan to take advantage of recent evidence that a substantial proportion of the UK population (two fifths) currently own a smartphone with 42% of these claiming that it is the single most important device for accessing the Internet<sup>12</sup> The authors also report that these smartphone users are rapidly turning away from the more traditional modes of accessing the Internet such as personal computers and laptops and, in particular young adult smartphone users use some sort of text-

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based application with over 90% using texts. We plan to exploit the easy access to Internet-based applications afforded to individuals with smartphones to administer a program of training to improve self-control. We will examine how smartphone technology permits the practical delivery of a self-control training intervention, 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 trail is recorded directly by the smartphone and uploaded to a university server. As opposed to using a personal digital assistant or personal computer, the smartphone and our linked server system offers a myriad of additional benefits such as the facility to ‘push’ requests to engage in a task at any time, effective storage of data through an immediate uplink of participant responses to the project server, and negating the need for multiple devices (e.g., an additional pager). Further any task-generated data is better protected because no data is stored directly on the phone and is, instead, saved on password-protected servers. This also overcomes the risk of losing data if the device is lost or stolen. The use of the current technology is has the advantage of providing 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<sup>6,7,8,9</sup> 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 four weeks of self-regulation training while participants allocated to a no-training control group received no training. In both experiments, we hypothesized that

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training would improve self-control strength and 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 design with the exception that we varied the depleting task used in the dual-task experiments across the two experiments in order to provide two tests of the effect and 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 US\$30 of shopping vouchers. Participants were randomly allocated to either a self-control training condition or no-training groups.

#### *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 colour-naming task; Study 2: a complex counting task) followed by a second self-control task (handgrip strength task in both studies). For the Stroop task participants engaged in seven trial blocks (approximately 10 minutes in duration) of Stroop items (238 colour-words in total) performed on a 15inch LCD computer screen with an achromatic grey background. Response time for each item was recorded. Each trial block comprised of 34 colour-words

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with a ratio of 25% congruent (e.g., the word RED written in RED-coloured ink) to 75% incongruent (e.g., the word RED written in YELLOW-coloured ink) colour-word stimuli. Each colour-word item was presented for a period of 2000 milliseconds (ms) with feedback duration of 800ms. Colour-word response options were presented in a vertical list directly below the current colour-word, selected by the participant using a PC mouse. The complex coordination-counting task requires participants to count backwards from 1000 in multiples of seven while standing on one leg, managing the complex counting and coordination components of the task requires considerable self-control.<sup>13,14</sup> The handgrip involved participants holding a commercially-available handgrip device for as long as possible. A coin placed between the handles of the grip when timing commenced and ceased when the coin dropped.<sup>15,16</sup> We took a baseline handgrip measure 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.

*Training tasks.* The intervention group engaged in four weeks of self-control training using a novel smartphone application while non-intervention group did not engage in any training. The training task was based on the Stroop paradigm<sup>17</sup> precisely as previously described in the ego-depleting task using the same computer application. The system was designed to be deployed on 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.<sup>5</sup> The training task is ego depleting because self-control needs to be repeatedly taxed in order for the training to be effective.

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

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native smartphone application in order to avoid constraining our participant group to a particular operating system (e.g., iPhoneOS™, Android™, Windows™ etc.). Prior to deployment the application was tested across a range of platforms and on a range of touchscreen smartphones (e.g., Samsung, HTC, Blackberry, iPhone). In all but three cases participants used their own touchscreen smartphone. We provided Nexus One Android™ touchscreen smartphones to the remaining three participants.

A linked web 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, seven days per week for four weeks. Each deployed task remained active until another task was deployed to measure compliance levels. A full description of the application can be found in Appendix A of the online supplementary material.

*Follow-up tasks and measures.* All participants were contacted by email or telephone and invited to return to the laboratory after four weeks. All participants agreed to return and they received an identical series of tasks 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.<sup>2</sup> Finally, participants were debriefed and thanked for participating in the study.

## **Results**

We calculated the difference in handgrip duration between the initial and post-depletion handgrip tasks for the dual-task pre- and post-training laboratory sessions and used these values as the baseline and follow-up dependent measures of ego depletion, respectively. We conducted a one-way ANCOVA 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

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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 we conducted a log transformation of the handgrip values<sup>1</sup>. Participants who completed the training intervention spent significantly longer (Study 1:  $M = +4.39s$ ,  $SD = 47.85$ ; Study 2:  $M = +0.07s$ ,  $SD = 31.63$ ) on the handgrip task than those who did not engage in any self-regulation training (Study 1:  $M = -24.26s$ ,  $SD = 39.65$ ,  $F(1,25) = 6.11$ ,  $p < .002$ ,  $\eta_p^2 = .196$ ; Study 2:  $M = -32.46s$ ,  $SD = 21.45$ ,  $F(1,30) = 15.09$ ,  $p < .001$ ,  $\eta_p^2 = .335$ ). There was also a significant but independent effect of trait self-control in Study 1 ( $F(1,25) = 5.40$ ,  $p < .05$ ,  $\eta_p^2 = .178$ ), but not in Study 2.

Across the four-week intervention period, overall intervention task compliance was high (Study 1: 72.78%; Study 2: 83.56%) and the mean percentage colour-word items correctly answered was also very high (Study 1: 98.10%; Study 2: 96.16%). The mean percentage of colour-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

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<sup>1</sup>The analysis was repeated using log-transformed data and the pattern was identical therefore only the untransformed scores are reported.

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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 non-dominant hand for everyday activities.<sup>10,11,6,9,7</sup>

In the present research, we specifically wanted to explore the efficacy of using a novel application delivered by smartphone to train self-control. We found that, overall, pervasive technology such as the smartphone is very useful, not only to deliver self-control training programs, but also to accurately measure performance and compliance levels 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,<sup>9</sup> 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.<sup>9</sup> 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. In addition, 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.

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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 allowing the researcher to investigate research questions out of research of conventional methods, providing ‘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).

### **Limitations and Future Directions**

The adoption of a novel an Internet-based training application delivered by smartphone to train self-control capacity was effective in producing increases in self-control strength in a handgrip task across two studies using separate tasks to induce ego depletion in dual-task paradigms. A notable limitation of the research, though, was its small sample size. Although the study was adequately powered to find significant effects, the studies should be replicated on a larger sample. In line with Hui and colleagues<sup>9</sup> 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 we anticipate that the results of these studies will help reduce the challenge of designing training interventions that are effective in a non-laboratory setting. In addition, future research should consider developing more 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.

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### **Author Disclosure Statement**

No competing financial interests exist.

### **References**

1. Tangney JP, Baumeister RF, Boone AL. High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality* 2004; 72: 271-324.
2. Baumeister RF, Heatherton TF. Self-regulation failure: an overview. *Psychological Inquiry* 1996; 7: 1-15.
3. Baumeister RF, Muraven M, Tice DM. Ego depletion: a resource model of volition, self-regulation, and controlled processing. *Social Cognition* 2000; 18: 130-150.
4. Baumeister RF, Vohs KD, Tice DM. The strength model of self-control. *Current Directions in Psychological Science* 2007; 16: 351-355.
5. Hagger MS, Wood C, Stiff C, Chatzisarantis NLD. Ego depletion and the strength model of self-control: a meta-analysis. *Psychological Bulletin* 2010; 136: 495-525.

6. Muraven M, Baumeister R F, Tice DM. Longitudinal improvement of self-regulation through practice: building self-control strength through repeated exercise. *Journal of Social Psychology* 1999; 139: 446-457.
7. Denson T F, Capper MM, Oaten M, Friese M, Schofield TP. Self-control training decreases aggression in response to provocation in aggressive individuals. *Journal of Research in Personality* 2011; 45: 252–256.
8. Gailliot MT, Plant E A, Butz D A, Baumeister R F. Increasing self-regulatory strength can reduce the depleting effect of suppressing stereotypes. *Personality and Social Psychology Bulletin* 2007; 33: 281-294.
9. Hui SK, Wright RA, Stewart CC, Simmons A, Eaton B, Nolte R N. Performance, cardiovascular, and health behavior effects of an inhibitory strength training intervention. *Motivation and Emotion* 2009; 33: 419-434.
10. Oaten M, Cheng K. Improved self-control: The benefits of a regular program of academic study. *Basic and Applied Social Psychology* 2006a; 28: 1-16.
11. Oaten M, Cheng K. Longitudinal gains in self-regulation from regular physical exercise. *British Journal of Health Psychology* 2006b; 11: 717-733.
12. OfCom (2011): <http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr11/uk/1.42>,  
<http://media.ofcom.org.uk/2011/08/04/a-nation-addicted-to-smartphones/>.  
(Retrieved Jan 15. 2013).
13. Hagger MS, Chatzisarantis NLD. The sweet taste of success: the presence of glucose in the oral cavity moderates the depletion of self-control resources. *Personality and Social Psychology Bulletin* 2012;39: 28-42.
14. Webb TL, Sheeran P. Can implementation intentions help to overcome ego-depletion? *Journal of Experimental Social Psychology* 2003; 39: 279-286.

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15. Martijn C, Tenbult P, Merckelbach H, Dreezens E, de Vries NK. Getting a grip on ourselves: challenging expectancies about loss of energy after self-control. *Social Cognition* 2002; 20: 441-460.
16. Muraven M, Tice DM, Baumeister R F. Self-control as a limited resource: regulatory depletion patterns. *Journal of Personality and Social Psychology* 1998; 74: 774-789.
17. Stroop J R. Studies of interference in serial verbal reactions. *Journal of Experimental Psychology* 1935; 18: 643-661.