Protocol for Registered Replication Report for *Perspectives in Psychological Science*

Title

Does ego-depletion exist? Multiple high-powered replications of the resource-depletion effect

Article Citation

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Rationale

In two key research articles, Baumeister and colleagues (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven, Tice, & Baumeister, 1998) proposed and tested a 'limited resource' model of self-control. According to their model, performance on tasks requiring self-control is governed by a general, unitary, and finite 'internal' resource. They proposed that engaging in tasks requiring self-control would lead to the depletion of the resource and reduced performance on subsequent self-control tasks. The state of reduced self-control capacity was termed 'ego-depletion'. Baumeister and colleagues tested their model using a 'dual task' experimental paradigm in which participants engaged in two consecutive tasks. For participants randomly allocated to the experimental (ego-depletion) group, both tasks required self-control while for participants allocated to the control (no depletion) group only the second task required self-control, with the first task not requiring any, or very little, self-control. The self-control tasks used typically required participants to alter or modify an instinctive, well-learned response such as resisting impulses or overcoming temptations (Baumeister, Vohs, & Tice, 2007). As predicted, participants in the experimental group performed worse on the second task relative to participants in the control group. Critically, the tasks used in the experiments were from different 'domains' of self-control providing evidence to suggest that the resource was 'domain-general' and was implicated in all tasks that required self-control. The limited resource account has received considerable support with numerous replications of the original findings using the dual-task paradigm. A meta-analysis revealed a medium effect size (d = 0.62) across 198 tests of the ego-depletion effect (Hagger, Wood, Stiff, & Chatzisarantis, 2010).

However, some researchers have questioned the strength of the effect or whether the effect exists at all. A recent analysis conducted by Carter and McCullough (2013; 2014) suggested that the effect may be an artefact of publication bias and the effect size reported by Hagger et al. (2010) may not be as large as previously reported. They cited evidence that many tests of the effect were substantially underpowered suggesting that the likelihood of finding such a large number of significant effects in the literature is improbable. Although the interpretation of these analyses have been questioned (Hagger & Chatzisarantis, 2014), the issue of bias is a real one. Both Carter and McCullough (2013; 2014) and Hagger and Chatzisarantis (2014) recommended that a series of large, pre-registered direct replications of the ego-depletion effect be conducted. We propose a

coordinated set of highly-powered (beta >.95) independent replications in multiple laboratories of the ego-depletion effect using a dual-task paradigm procedure developed and published by Sripada, Kessler, and Jonides (2014), which is very similar to that used in the original depletion experiments (Baumeister et al., 1998; Muraven et al., 1998) using computerised versions of tasks to minimise variability across laboratories. The proposed research will make a unique contribution to the self-control literature by providing appropriately-powered replications of the ego-depletion effect across multiple laboratories.

Materials

The protocol for the proposed replication adopts the original materials used in the replicated study supplied by Sripada et al. The materials for the experiment include:

1. Laboratory setup with desk and standard desktop computer with *E-Prime* (v. 2) software
2. A step-by-step procedure (see separate file "A_Step_by_Step_procedure.pdf")
3. Information sheets, consent forms and debrief sheets (see separate file "B_Consent_forms.pdf")
4. Computerized versions of two tasks to be used in the dual-task paradigm: a letter 'e' task ('easy' or 'regulation' and 'hard' or 'control' practice and main-trial versions) and a multi-source interference task (MSIT; practice and main-trial versions) programmed in *E-Prime* supplied by the original authors (see separate file "C_Running_E_prime_tasks.pdf")
5. Questionnaire measures of perceived effort, difficulty, fatigue, and frustration (see separate file "D_Questionnaire.pdf")
6. A data analysis package programmed in 'R' to prepare the MSIT data for analysis (see separate file "E_Data_collation_and_analysis.pdf")

All of these materials are provided in the Open Science Framework project page for this registered replication

Important: If your lab does not have a license for *E-Prime*, you may still participate in the replication, we can supply you with a 'Run Time' license for *E-Prime* so that your lab can collect data for the replication. If this is the case you will need to indicate on the replication proposal form (see "SripadaRRR_ApplicationToParticipate_Form.doc") that you do not have a license for *E-Prime* and will require the 'Run Time' license.

Methods

Design. The experiment adopts a one-way experimental design based on Sripada and colleagues' (2014)[1] study. The study adopted easily-replicable computer-based self-control tasks that have been used in a large number of other dual-task paradigm studies testing the ego-depletion effect. In addition, the study has

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[1]Note that Sripada and colleagues' also investigated the moderating effects of methylphenidate (Ritalin®) on ego-depletion using a 2 (depletion: depletion vs. no depletion) x 2 (methylphenidate: drug vs. placebo) design. We aim to replicate only the dual-task depletion paradigm component of the experiment in the current proposed study.

a clear and precise protocol and mirrors the dual-task paradigm used in previous studies including the original tests (Baumeister et al., 1998; Muraven et al., 1998). The protocol is designed to ensure accurate replication of the experiment across laboratories.

Procedure. Participants are expected to be recruited from undergraduate participant pools for a study on "word and number recognition and reaction time". Participants are randomly allocated to experimental (ego-depletion) or control (no depletion) groups. Participants are welcomed by the experimenter, shown into the laboratory, and asked to sit behind a computer desk. They are informed that they will be required to engage in two computer-administered tasks, presented consecutively, after a period of practice on each task. Participants then complete practice versions of the two tasks. The first task is the letter 'e' task and the second task is a modified multi-source interference task (MSIT). Both tasks are presented on a computer screen controlled by *E-Prime* experimental software. After the practice sessions, participants proceed to the main trials of each task. After completing the first task, brief measures of task effort, difficulty, fatigue, and frustration are administered and used as manipulation checks for the depletion manipulation. After completing the self-report measures, participants proceed directly to the second task.

Letter 'e' task. The initial task is a modified version of the letter 'e' task with standardized instructions administered using *E-Prime* experimental presentation software (see separate file "C_Running_E_prime_tasks.pdf"). Two versions are used: 'regulation' and 'control'. In the regulation version administered to the experimental (depletion) group, participants are presented with a series of words on a video screen and required to press a button when a word with the letter 'e' is displayed, but must withhold the response if the 'e' is next to or one letter away from a vowel. The control version administered to the control (no depletion) group is matched in all respects with the exception that participants are required to press a button whenever a word with the letter 'e' is displayed with no requirement to withhold their prepotent response to the stimulus. In both versions of the task, participants are required to engage in a brief practice period before the commencement of the experiment. The main trial version comprises 150 trials and lasts for 7 minutes 30 seconds. Participants' reaction times and errors for the letter 'e' task are recorded by the *E-Prime* program.

Multi-source interference task (MSIT). The MSIT task is a computer-administered task requiring response inhibition (Bush, Shin, Holmes, Rosen, & Vogt, 2003). The task is a standardized version available on *E-Prime* experimental software (see separate file "C_Running_E_prime_tasks.pdf"). Numeric stimuli are presented on the computer screen with participants making responses using the keyboard. Participants are asked to place their index, middle and ring fingers of the right hand on three keys on the keyboard. Participants are told that they will be presented with sets of three numbers (1, 2, 3 or 0) in the center of a video screen every few seconds, and that one number (the target number) will always be different from the other two (matching distractor) numbers. Participants are told that they need to identify the target *number* not its *position* in the set of numbers. Participants are required to depress the key corresponding to the number that differs from the other two. In 'control' number sets, the target number (1, 2 or 3) always matches its position on the response keys, such as the number '1' appearing in the first (leftmost) position. For example, number sets 100, 020 or 003 are examples of 'control' sets. In 'interference' or 'incongruent' number sets, the target number (1, 2 or 3) never matches its position on response keys, and the distractors are

themselves potential targets. For example, for the number set 233 the correct response would be '2'. The task creates interference in the identity of the target number and its position and size relative to other numbers on the string, requiring the participant to inhibit the position and size of the target number in favor its identity. The task lasts approximately 10 minutes and comprises 200 trials, 100 control (congruent) and 100 interference (incongruent) trials presented in an interspersed, pseudorandom order.

Reaction time and error data are logged by the E-Prime program. Performance on the second task (MSIT) is the dependent measure of regulatory performance. The MSIT provides data on two performance measures: mean reaction time on incongruent trials and reaction time variability (RTV) on incongruent trials, defined as the ex-Gaussian distribution functions (Dawson, 1988; Sripada et al., 2014). RTV on the MSIT is the primary dependent variable for the critical test of the depletion effect in the current replication as it is believed to more effectively capture lapses in attention than absolute performance. Attentional control is the critical process in response inhibition tasks in order to maintain consistent task-directed focus and supress task-irrelevant spontaneous thoughts. Reduction in attentional control induced by depletion is likely to lead to more lapses in attention, manifesting as increased variability in response latencies across trials on the MSIT (Weissman, Roberts, Visscher, & Woldorff, 2006).

Practice sessions. After being introduced to the experiment participants will first engage in practice versions of both the letter 'e' task and MSIT tasks. The practice sessions are 'front loaded' to minimise transition time between the initial and second tasks in the depletion paradigm.

Debrief. In an exit questionnaire, participants are probed for suspicion as to the purpose of the experiment. They are then thanked, provided with a full debrief, and informed that the experiment has concluded.

Critical comparisons

The critical test is comparison of the MSIT performance for the experimental (ego-depletion) group to that of the control (no depletion) group. Our primary dependent variable is reaction time variability (RTV) during incongruent trials of the MSIT (using ex-Gaussian modeling, RTV is defined as the sum of the sigma and tau variability parameters). We expect increased reaction time variability among participants assigned to the difficult letter 'e' task (depletion) condition compared to participants assigned to the easy letter 'e' task (control) condition. This is identical to the critical tests conducted in the replicated experiment (Sripada et al., 2014). It is also consistent with the critical tests in the original ego-depletion experiments (Baumeister et al., 1998; Muraven et al., 1998) and those in the extant literature.

We will also conduct secondary analyses on another dependent variable from the MSIT: mean reaction time. This is consistent with analyses conducted for similar interference tasks in the literature, such as the Stroop color-naming task. We predict significantly greater reaction times among participants assigned to the depletion group relative to participants assigned to the control group.

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Protocol Requirements

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Sample size

Effect sizes from previous studies adopting the two proposed tasks as dependent variables provide a guideline effect size for computing the sample size. The averaged effect size based on ego-depletion studies using the letter 'e' task as the dependent variable corrected for sampling error using the meta-analytic techniques adopted by Hagger et al. (2010) is $d = 0.77$ and the averaged corrected effect size of the studies using the Stroop color-naming task as the depleting task is $d = 0.77$, with the Stroop task being closest to the MSIT used in the dependent task in the current replication. However, in order to provide a conservative estimate, we consider the overall effect size found across all tasks in the meta-analysis of the ego-depletion effect ($d = 0.62$). Setting alpha at 0.01 and beta at 0.95, a statistical power analysis using G*Power v. 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) yields a total sample size of N ≥ 168, with n ≥ 84 in each condition. While we strongly recommend that participating laboratories' replications meet this guideline sample size, replications with total sample sizes of 100 (n ≥ 50 in each condition) will be acceptable.

Sample demographics

• Undergraduate participant pool or equivalent, preferably of approximately equal gender distribution.
• Age range 18-30 years - there is evidence to suggest that older samples may experience less ego-depletion that younger samples, hence the restriction (Dahm et al., 2011).
• Participants need to be native speakers of the language in which the letter 'e' task stimuli are presented.
• LABS THAT WISH TO CONDUCT THE REPLICATION WITH NON-ENGLISH SPEAKING PARTICIPANTS will need to have a fluent bi-lingual translator translate the materials into the required language followed by a back-translation by an independent fluent bilingual translator. This includes the word stimuli in the letter 'e' task and the instruction slides. This is to ensure there are no discrepancies from the original. Both stages of the translation procedure should be documented on the Open Science Framework page of the participating lab. Assistance in embedding the word stimuli and instruction slides into the *E-Prime* program for the letter 'e' task will be arranged. It is important to note that replications from non-English speaking labs will be analysed separately to those from English-speaking labs.

Testing location

• In-person testing in laboratory conditions (must not be conducted online).
• Participants must tested in isolation (must not be tested in groups).

Experimenters

• No special expertise is necessary to conduct the study.
• Any trained assistant, postdoctoral, or faculty researcher is eligible to serve as experimenter.
• Experimenters should have experience collecting experimental psychology data and interacting with participants.

• Experimenters should be familiar with the step-by-step procedure (see separate file "A_Step_by_Step_procedure.pdf") and practice using the proposed methods prior to data collection.
• We strongly recommend that experimenters are naive to the experimental conditions. Participating labs should make a note at to whether experimenter naivety is implemented successfully for the course of the experiment.

Data collection

• Replicating laboratories should record the basic demographic data of all participants. Demographic data should be collected at the beginning of the session in a very brief demographic questionnaire recording only the participant's age, gender, and native language. Native language is collected to ensure that participants' native language matches the language in which the letter 'e' task stimuli are presented.
• Researchers must use the standardized letter 'e' task and MSIT programmed in *E-Prime* supplied as part of the methods protocol (see separate files "A_Step_by_Step_procedure.pdf" and "C_Running_E_prime_tasks.pdf"). Responses on the letter 'e' task and MSIT will be logged automatically by the *E-Prime* experimental software and errors computed (see "C_Running_E_prime_tasks.pdf").
• Responses to the manipulation check items (measures of effort, difficulty, fatigue, and frustration; see "D_Questionnaires.pdf") can be made on a pen-and-paper questionnaire or on a computer using an online survey tool such as Survey Monkey (at the discretion of the research team).
• Participants should be unaware of the experimental hypothesis and kept blind to the link between the initial and subsequent tasks in the dual-task paradigm.
• The signup for the study should describe it as a study study of attention, thought, and behavior (see sample information sheets, consent forms and debrief sheet; see "B_Consent_forms.pdf").
• Participants must be tested in isolation in a laboratory cubicle or similar and individually (not in groups)
• Participants should be assigned to the experimental (ego-depletion) and control (no depletion) conditions using pseudo-random assignment. This is done by generating a list of condition assignments (e.g., 90 "ego-depletion" and 90 "Control"), randomizing the order of that list, and then assigning participants to conditions in the order of that list schedule. This can also be done using a computerised randomising schedule such as *Research Randomizer* (Urbaniak, Plous, & Lestik, 2007) with the constraint that approximately equal numbers of participants are assigned to each condition. However, it is anticipated that some participants will need to be excluded based on criteria specified a priori (see below). In order to preserve approximately equal numbers of participants across conditions and achieve the minimum numbers required in each condition (n = 84), data should be collected from blocks of 10 participants (with 5 assigned to each condition and order randomized, consistent with the pseudo-randomisation procedure) until both conditions meet the minimum required sample size. As a result, one condition might have more participants than the other, due to different rates of exclusion, but both will meet the required minimum.

Data from a participant will be excluded if:

• They did not follow instructions on the experimental or control task.

• They did not complete all tasks.
• Their accuracy is less than 80% on the MSIT trials and participants mean reaction times and/or mean reaction time variability on incongruent trials of the MSIT are more than two SDs above sample mean
• The experimenter incorrectly administered the task or instructions (we have included standardized tasks for administration by computer to minimize experimenter variation; see "C_Running_E_prime_tasks.pdf").

Note: Any excluded data and the reason for exclusion MUST be identified and included in the data sets.

Required Data Analyses

• Data preparation: Scripts for preparing the data and computing the reaction time variability (RTV) variables for analysis in the 'R' statistical package are supplied with the protocol (see separate file "E_Data_collation_and_analysis.pdf"). These scripts will compute mean reaction time and ex-Gaussian fitted RTV variables for the incongruent trials of the MSIT task. Only accurate reaction times are included, inaccurate responses and non-responses are excluded.
• Main hypothesis test: Compute two independent samples *t*-tests, with correction for multiple tests, comparing differences between the experimental and control groups on the two key dependent variables: the ex-Gaussian fitted RTV (labelled 'ExGauss.I.RTVar.MSIT' in the output file) and mean reaction time variables (labelled 'I_1_MeanRT.MSIT' in the output file) for the incongruent items of the MSIT.

We also recommend that researchers compute the following additional tests: (1) tests of difference (e.g., *t*-tests) comparing participants' mean ratings of effort, fatigue, difficulty, and frustration across the ego-depletion and control conditions (with positive *t*'s indicating larger rating in the ego-depletion group) and (2) a test of difference (e.g., one-way ANOVA) comparing the overall accuracy on the letter 'e' task (labelled 'Acc.Overall.LetE' in the output file) across the hard (ego-depletion) and easy (control) conditions.

Expected Completion

• Completion of data collection and analysis for all participating labs is expected by July 31, 2015.

Procedure

(1) Participants are recruited to a study on "word and number recognition and reaction time" (see full step-by-step protocol in separate file "A_Step_by_step_procedure.pdf").

(2) Participants are randomly assigned to depletion or no-depletion experimental conditions according to a priori randomization schedule.

(3) Participants are seated in front of a computer in isolation and complete experiment information and consent forms (see separate file "B_Consent_forms.pdf").

(4) Participants are read instructions for the practice letter 'e' task and are presented with the instructions for the task on the screen using the *E-Prime* program. Participants either receive the regulation (depletion) or non-regulation (control) versions of the practice letter 'e' task (see separate file "C_Running_E_prime_tasks.pdf").

(5) Participants read instructions for the practice multi-source interference task and are presented with task instructions on the screen using the *E-Prime* program. All participants receive the same instructions and version of the task.

(6) Participants are re-read the instructions for the letter 'e' task and asked to complete the main trial version of the letter 'e' task, regulation or non-regulation versions according to the randomization schedule.

(7) Participants complete a 4-item questionnaire on effort, difficulty, fatigue, and frustration (see separate file "D_Questionnaires.pdf").

(8) Participants re-read the instructions for the multi-source interference task and then complete the main trial version of the multi-source interference task.

(9) Participants are provided with a funnel debrief to test awareness of purpose of study (see separate file "A_Step_by_Step_procedure.pdf").

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