Drift diffusion modeling of ego-depletion effects on Stroop task

Previous research has shown that performance on tasks involving speed-accuracy tradeoffs can be described by parameters (e.g., drift rate, threshold) in the drift diffusion model (Wagenmakers et al., 2007; Ratcliff et al., 2016). For example, faster drift rates reflect faster information accumulation rates, while larger thresholds reflect greater cautiousness, in that more information has to be accumulated before one makes a decision. Here, we will investigate whether ego depletion leads to changes in two key parameters of the diffusion model: drift rate (i.e., processing efficiency or the amount of evidence accumulated per unit time) and reduced threshold (response caution or the amount of evidence required before response is made). Exploratory analyses in previously collected data suggest that depletion leads to reduced drift rate (reduced information accumulation rates) and reduced threshold (reduced cautiousness). In these studies, the depletion task was 20 minutes.The present study aims to replicate these effects using the same depletion task but with a shorter duration.

Experimental conditions and design

There are two conditions in this **within-subjects design**: After completing the control task (watching a 5-minute video) or depleting task (5 minutes), participants will complete questions that assess subjective experience (i.e., boredom, effort, frustration, fatigue, mental demand). Then, to measure ego-depletion effects, participants will complete a modified Stroop task (dependent variable). Participants will be randomly assigned to either the control or depleting condition on the first day. They will then complete the other experimental condition approximately a week later.

Control task: video

Participants will watch a wildlife video that lasts approximately 5 minutes (https://www.youtube.com/watch?v=Q52ZXTZK_dc&t=1s). We have opted to use this 5-minute video as the control task to avoid inducing boredom (easy cognitive tasks often induce boredom), which might also impair cognitive performance in a similar fashion to depletion.

Titrated depletion task: Modified symbol counter task (5 minutes)

To induce depletion, we will use the symbol counter task, which has been shown to differentially activate brain regions associated with working memory as a function of trial difficulty (for task details see Garavan, Ross, Li, & Stein, 2000). This task requires participants to count the number of small and big squares presented on each trial, and requires mainly two components of executive function (i.e, updating, shifting). We will use a modified version of this task that adjusts its difficulty on a trial-by-trial basis via three parameters:

1. Number of squares presented (11 to 17)
2. Switch frequency (i.e., how frequently it switches from big to small or small to big square; there are four levels of difficulty)
3. Display duration of each square (starts at 800 ms)

The first actual trial presents 12 squares at switch frequency difficulty level 2. If participants get this trial correct, the next trial will have 13 squares and the display duration will decrease by 20 ms (from 800 ms to 780 ms). That is, the number of squares increases by 1 and display duration decreases by 20 ms each time participants respond correctly. Whenever they make a mistake, the number of squares presented will decrease by 1 and display duration will increase by 20 ms. If they are at 17 squares at switch frequency 2, the next trial will present 11 squares at switch frequency difficulty level 3 (if they get the current trial correct).

On each trial, a square is presented and is preceded by a fixation cross (250 ms). The task begins with two practice trials with feedback indicating whether participants have counted the correct number of squares correctly. After which, the actual task begins and no feedback will be provided. Participants will perform the task for 5 minutes.

Dependent/outcome measure: Stroop
Participants will complete a Stroop task (3 colours: red, blue, yellow; adapted from Stroop, 1935). They will complete 180 trials (120 congruent, 60 incongruent), presented in two blocks (90 trials each), with no break between blocks. On each trial, the stimulus will remain on screen until the participant responds or until a maximum of 2000 ms. If participants fail to respond on 3 consecutive trials, a message will be shown to remind them to respond faster and more accurately.

Exclusion criteria
Titrated depletion task: Modified symbol counter task

- Participants whose overall accuracy is less than 20%

Dependent measure: Stroop task

- Trials with reaction time < 250 ms
- Trials with reaction time > 3 median absolute deviations (MAD) from individual's overall reaction time, within each experimental condition
- Participants whose total number of errors on congruent trials > 3 MADs from the overall median, within each experimental condition

Demographic measures

- Age, gender, ethnicity, perceived socio-economic status

Primary hypotheses

1. Depletion (vs. control) condition will be associated with *reduced drift rate*, after controlling for congruency effects.
2. Depletion (vs. control) condition will be associated with *reduced threshold*, after controlling for congruency effects.

Sample and power
Based on effect sizes from our exploratory analyses of a previous data set with a depletion task that lasted about 15 minutes (drift rate and threshold effect sizes: d ≈ 0.26–0.31), we expect similar but smaller effect sizes in the current study because of the shorter (5 minutes)

depletion task. Thus, we will recruit **up to** 128 participants (see optional stopping in next section) from Amazon MTurk, which will give us at least 80% statistical power.

Frequentist testing and Bayesian optional stopping

To reduce recruitment resources, we will conduct sequential Bayes analyses, which allow for optional stopping. When the total sample size n is smaller than the target sample size stated above, we will use sequential Bayes factor (Schönbrodt et al., 2015, 2016) during data collection to assess the strength of evidence in favor of our experimental hypothesis. Specifically, we will compute the Bayes factor for about every 30th participant recruited. Unlike classical frequentist testing, the Bayesian approach allows for unlimited multiple testing, even after each participant. We will stop data collection once the Bayes factor is 5 or greater in favor of either the experimental hypothesis or the null hypothesis any point during data collection. Thus, our final sample size might be smaller than the target sample size. We will only use classical frequentist methods—independent t-test once our Bayes factor is 5 or greater in favour or the alternative or null hypothesis, or when our final sample size has been reached (see power calculation above). That is, we will only use classical frequentist methods once we have stopped data collection.

Bayes factors for primary hypotheses

We will also supplement the two effects above with Bayes factors, computed using JASP with a Gaussian prior (mean = 0.28, SD = 0.14) truncated at 0 to allow only positive effect sizes (a similar prior have used analyse recent ego-depletion effects; see https://www.bayesianspectacles.org/redefine-statistical-significance-xiii-the-case-of-ego-depletion/). Dienes (2014) also suggested to use SD = mean/2 for a Gaussian distribution.

Secondary predictions based on pilot data

We have also observed other findings in our pilot data and expect to replicate them. While we are predicting to replicate these effects, they are not tests of ego depletion effects.

1. Incongruent (vs. congruent) trials will be associated with lower drift rates.
2. Incongruent (vs. congruent) trials will be associated with lower thresholds.
3. Depletion (vs. control) condition will report increased mental demand, effort exerted, frustration, boredom, and fatigue after completing the initial task.
4. Participants who report feeling more frustrated after the initial task will have lower drift rates and thresholds.
5. Participants who report feeling more bored after the initial task will have lower drift rates and thresholds.
6. Participants who report feeling more tired after the initial task will have lower drift rates and thresholds.

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