Cognition 172 (2018) 101–106

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/cognit

Brief article

# Cognitive capacity limitations and Need for Cognition differentially predict reward-induced cognitive effort expenditure

Dasha A. Sandra[1], A. Ross Otto[1,*]

*Department of Psychology, McGill University, Montreal, Quebec H3A 1G1, Canada*

ARTICLE INFO

*Keywords:*
Cognitive effort
Decision-making
Executive function
Reward
Cognitive control

ABSTRACT

While psychological, economic, and neuroscientific accounts of behavior broadly maintain that people minimize expenditure of cognitive effort, empirical work reveals how reward incentives can mobilize increased cognitive effort expenditure. Recent theories posit that the decision to expend effort is governed, in part, by a cost-benefit tradeoff whereby the potential benefits of mental effort can offset the perceived costs of effort exertion. Taking an individual differences approach, the present study examined whether one's executive function capacity, as measured by Stroop interference, predicts the extent to which reward incentives reduce switch costs in a task-switching paradigm, which indexes additional expenditure of cognitive effort. In accordance with the predictions of a cost-benefit account of effort, we found that a low executive function capacity—and, relatedly, a low intrinsic motivation to expend effort (measured by Need for Cognition)—predicted larger increase in cognitive effort expenditure in response to monetary reward incentives, while individuals with greater executive function capacity—and greater intrinsic motivation to expend effort—were less responsive to reward incentives. These findings suggest that an individual's cost-benefit tradeoff is constrained by the perceived costs of exerting cognitive effort.

## 1. Introduction

Goal-directed behavior is constrained by the capacity limitations of cognitive processing—for example, an individual's working memory capacity, or the amount of the information to which an individual can simultaneously attend. Because cognitive processing is inherently resource-limited, our decision to engage in effortful cognitive processing should be dictated, in part, by its costs and benefits. According to a recent influential account of cognitive control, the utility of expending cognitive effort is, simply put, the expected benefit obtained by exerting cognitive effort minus the cost of this effort exertion (Shenhav, Botvinick, & Cohen, 2013).

Underlining this point, people consistently avoid exertion of cognitive effort (Inzlicht, Schmeichel, & Macrae, 2014; Westbrook & Braver, 2015), and effort avoidance is more prevalent in individuals with limited cognitive ability (Kool, McGuire, Rosen, & Botvinick, 2010). That is, the cost of effort expenditure appears to weigh more heavily for cognitive capacity-limited individuals, and as a result, these increased internal effort costs drive decisions towards less cognitively effortful courses of action (Kurzban, Duckworth, Kable, & Myers, 2013).

At the same time—and again in accordance with the notion of a cost-benefit tradeoff—when large reward incentives hinge on successful deployment of controlled processing, people increase their level of cognitive effort expenditure relative to circumstances when reward incentives are smaller or nonexistent (Aarts et al., 2014; Bijleveld, Custers, & Aarts, 2010; Capa, Bouquet, Dreher, & Dufour, 2013; Hübner & Schlösser, 2010; Locke & Braver, 2008; Padmala & Pessoa, 2011) For example, in the Stroop task, large potential rewards enhance the processing of task-relevant stimulus information, resulting in faster and more accurate responding (Krebs, Boehler, & Woldorff, 2010). This body of work suggests that reward incentives can effectively offset perceive effort costs, and in doing so, 'mobilize' cognitive processing resources in the service of goal-directed behavior (Botvinick & Braver, 2015).

Considering these two separate lines of research together yields a compelling and untested question: how might an individual's cognitive capacity predict the extent to which reward incentives can mobilize cognitive effort? As cognitive costs may loom larger for individuals with smaller cognitive capacities because they tend to avoid effort expenditure (Kool et al., 2010), and reward incentives can increase the net utility of cognitive effort expenditure by offsetting its costs, one possibility is that the mobilizing effects of reward incentives should be

* Corresponding author at: Department of Psychology, McGill University, 2001 McGill College Ave, Montreal, QC H3A 1G1, Canada.
*E-mail address:* ross.otto@mcgill.ca (A.R. Otto).
[1] Authors contributed equally to this submission.

https://doi.org/10.1016/j.cognition.2017.12.004
Received 10 July 2017; Received in revised form 1 December 2017; Accepted 4 December 2017

greater for lower-capacity individuals (for whom these costs are large) than for higher-capacity individuals (for whom these costs may be negligible). Alternatively, lower-capacity individuals might be less responsive to reward incentives, as these benefits have larger costs to offset, and therefore, the marginal utility of increasing effort expenditure is smaller for these individuals.

By changing the benefits associated with effort exertion while keeping task difficulty constant, we can disambiguate between these two predictions: in the former account, we should expect to see a marked increase in effort exertion among individuals for whom effort costs are perceived to be large (i.e., the effective load on processing resources is high) but not among individuals for whom these effort costs are small, while in the latter account, we should instead expect higher-capacity individuals, for whom these effort costs are perceived to be low and therefore the marginal utility of increased effort larger, to increase their effort exertion.

To test these possibilities, we manipulate the amount of reward tied to performance in a simple task-switching paradigm that requires participants to frequently switch between two tasks (Monsell, 2003). The pervasive "switch costs"—the difference in response times (RTs) between task switches and task repetitions—result from task-set reconfiguration processes that are demanding of central executive resources (Monsell, 2003). Following previous work (Braver, Reynolds, & Donaldson, 2003; Kool et al., 2010), we interpret a reduction in switch costs as an indication of increased cognitive effort investment.

Separately, we measure each individual's Stroop incongruence effect, taken here as a measure of executive-dependent processing ability (Kane & Engle, 2003), and accordingly, examine how this processing capacity bears upon reward-induced modulations of task switch costs. While the Stroop and task-switching rely, in part, on shared executive functions (Miyake et al., 2000), they also make unique requirements upon response inhibition and task-set shifting processes, respectively. The use of qualitatively different cognitive control tasks to separately assess baseline individual differences and responsivity to reward incentives minimizes the possibility of (near) transfer of practice between the two tasks and further, highlights the generalizability of the relationship between inherent capacity limitations and decisions about effort expenditure.

We also examine the possibility that individuals might vary in how they value cognitive effort, independent of cognitive ability, as operationalized by the Need for Cognition scale (NFC; Cacioppo, Petty, & Kao, 1984). Indeed the NFC scale predicts the amount of money an individual will forego to avoid cognitive effortful activity (Westbrook, Kester, & Braver, 2013). By the same token, we would expect here that individuals high in NFC— who place more intrinsic value on effort expenditure—should be less responsive to monetary incentives in Task-switching, relative to low-NFC individuals. That is, to the extent that high-NFC individuals place intrinsic value in exertion of cognitive effort (or simply do not treat it as costly), we expect that these individuals should be less sensitive to the costs and benefits of cognitive effort exertion, and accordingly, should exhibit a smaller reward-induced reduction in task switch costs.

## 2. Methods

### 2.1. Participants and design

54 participants were recruited through McGill participant pool and the university community and gave written consent in accordance with the McGill Research Ethics Board. Prior to the main task, participants completed the NFC scale, an 18-item questionnaire which measures the extent to which individuals engage with and enjoy cognitively demanding activities (e.g., "I prefer complex to simple problems" and "I prefer my life to be filled with puzzles I must solve"; (Cacioppo et al., 1984). We also administered the behavioral inhibition system/behavioral activation system scales (BIS/BAS; Carver & White, 1994) to assess individual differences intrinsic motivation and reward sensitivity respectively, also part of our standard laboratory questionnaire battery, we administered the Barratt Impulsiveness (Patton, Stanford, & Barratt, 1995) and the Generalized Anxiety Disorder (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006) scales.

Participants completed one block of a Stroop task followed by two separate task-switching blocks in which the reward for correct responses (High Reward versus Low Reward) was manipulated as a counterbalanced, within-subjects factor. We excluded the data of 7 participants who failed to perform either task with an accuracy of at least 80% and 2 participants who missed 15 or more response deadlines in any block of the experiment, leaving 45 participants in the final analyses. We further excluded 2 participants with missing NFC questionnaire responses from analyses using NFC questionnaire data.

### 2.2. Stroop task

Participants performed a computerized version of the Stroop task (Otto, Skatova, Madlon-Kay, & Daw, 2015) which required them to identify, as quickly and as accurately as possible, which one of three colors the word on the screen was presented: red, green, or blue, by pressing one of three keys ('j', 'k,' and 'l' respectively) while ignoring the meaning of the word (Fig. 1A). Before starting with the task, the participants first completed a short practice block to get them accustomed to the task. Each Stroop block consisted of 120 trials, 30 incongruent and 90 congruent. On each trial, the participant saw the stimulus (a color word sized $100 \times 350$ pixels) 500 ms after the onset of the trial. The participant then had 1.5 s to make a response. No feedback was provided. RGB color codes (255, 0, 0), (0, 255, 0), (0, 0, 255) were used for red, green, and blue respectively.

### 2.3. Task-switching paradigm

After performing the Stroop, participants were informed that they

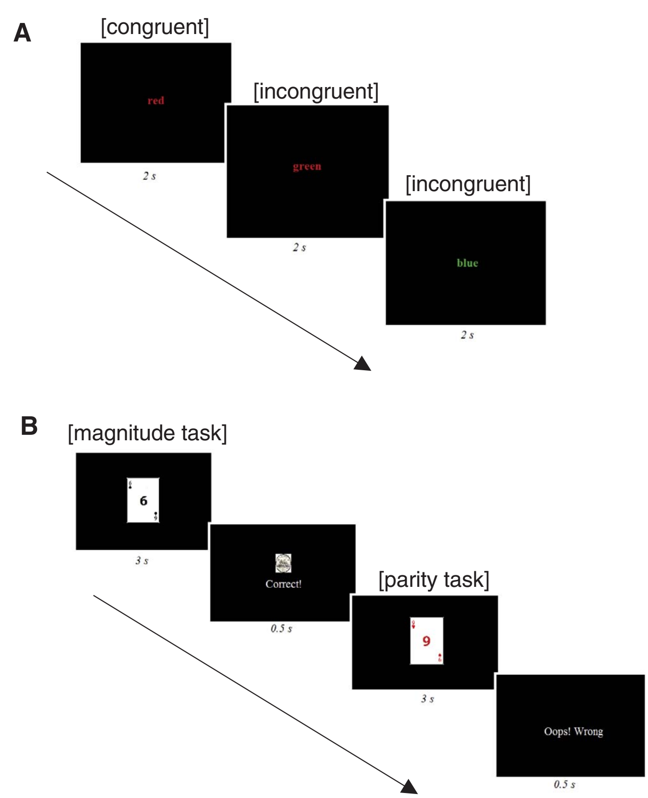


**Fig. 1.** (A) Computerized Stroop task. (B) Task-switching paradigm.