# The effect of task switching on cognitive fatigue

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## Abstract

**Little is known about how task switching moderates the relationship between cognitive effort and cognitive fatigue. To that end, we developed a novel paradigm using an objective measure of cognitive fatigue—participants' willingness to spend money on rest following periods of cognitive exertion. Across the experiment, epochs characterized by poor performance ("low-efficacy") were followed by significantly increased cognitive fatigue. This effect was potentiated when subjects anticipated an upcoming task switch. Crucially, the impact of undergoing a task switch on subsequent performance also depended on prior task efficacy: switching into a new task improved performance after low-efficacy epochs but impaired it after high-efficacy epochs. These results use an objective measure to replicate prior findings that cognitive fatigue worsens after low-efficacy tasks. Further, they demonstrate an intriguing role for task-switching in cognitive fatigue. Task-switching is costly to performance only during high-efficacy periods; in low-efficacy periods, undergoing a switch enhances performance. Given the relationship between performance and cognitive fatigue, this also suggests that switching into a new task while in a low-efficacy state improves fatigue. While these relationships must be further examined, our findings implicate strategic task switching as a potentially effective intervention for managing performance declines and fatigue during cognitively demanding tasks.**

**Keywords:** cognitive fatigue; task switching; effort allocation; switch cost; effort valuation

## Introduction

Adjusting effort as the environment changes is crucial to pursuing and achieving goals. Cognitive fatigue constrains this ability by making certain tasks feel more difficult or almost impossible. Understanding the dynamic relationship between cognitive effort and cognitive fatigue is critical to understanding human behavior.

Prior research identifies task efficacy (how much additional reward will be gained with additional effort) and expected reward as two important factors for determining effort allocation in dynamic environments (Frömer, Lin, Dean Wolf, Inzlicht, & Shenhav, 2021). This process is complicated; while exerting effort can enhance value of an object or stimulus, cognitive effort is consistently shown to be costly (Boksem & Tops, 2008; Inzlicht, Shenhav, & Olivola, 2018; Kool, McGuire, Rosen, & Botvinick, 2010; Shenhav et al., 2017), with fatigue the subjective "read-out" of this cost (Bijleveld, 2023; Matthews et al., 2023).

Cognitive fatigue manifests as a subjective feeling of tiredness, a decrease in task commitment, or impaired performance (Boksem & Tops, 2008). Cognitive fatigue grows over extended periods of cognitive effort, and recent studies using self-report reveal that poor task performance increases subjective cognitive fatigue as well (Matthews et al., 2023; Xu, Frömer, Wolff, & Shenhav, 2023). This indicates that lower efficacy task states are associated with cognitive fatigue and supports the adaptive signal hypothesis, which proposes that fatigue signals that continuing to perform a task is no longer worth the effort (Bijleveld, 2023). One implication of these findings is that switching to a different task once fatigued may reduce the experience of cognitive fatigue, and consequently manifest as an improvement in performance.

Our research investigates whether task switching reduces cognitive fatigue and improves performance during low-efficacy task states. Specifically in this study, we aimed to replicate previous findings of a fatigue-error relationship using an objective measure of cognitive fatigue as well as determine if the impact of task switching on cognitive fatigue is task state (low vs. high efficacy) specific.

## Methods

We developed a novel paradigm conducted online for approximately 55 minutes (N=90, N=84 post-exclusion). After an instructional period, participants were taken through a training phase of three "games": a spatial recall game (memorizing 4 squares flashing on a 4x4 grid), a digit span game (memorizing 4 digits flashing on screen), and a low effort rest game (clicking the digit corresponding to a given shape, with no memory required). The spatial recall and digit span games were referred to as Game A and Game B (counterbalanced across participants).

In the main phase after training, participants were shown 10 blocks of the games in the order: ABABBABAAB. Each block consisted of 3 epochs of the same game, and every epoch was followed by a self-paced rest (SPR) period (described below in more detail). Here, each SPR period was preceded by a cue that signaled whether, in the following epoch, participants would be playing the same game (a task stay) or a different game (a task switch).

Importantly, this experiment incorporated the aforementioned SPR periods, each consisting of 20 1.5 second trials of the low effort rest game. Participants could terminate SPR periods at their discretion. Following the conclusion of the 10 blocks, participants finished the rest trials they had skipped to equalize the length of the experiment. Crucially, the decision to remain in rest was costly. Participants were told they would lose points from an initial 600 point endowment for every second they remained in rest, and that the total points remaining after task completion would be used to calculate a monetary bonus. Thus, in contrast to prior work which has relied primarily on subjective (self-reported) fatigue, rest duration–indexing participants' willingness to incur a cost to continue resting—is used here as an objective measure of cognitive fatigue.

## Results and Discussion

Using a negative-binomial mixed effects model to predict SPR length, we found that a decrease in epoch performance was significantly associated with increased subsequent rest time. This supports prior findings of a post-error increase in fatigue and the notion that cognitive fatigue is related to task efficacy. Importantly, there was also a significant interaction between task efficacy and task switching on fatigue. During periods of low efficacy (decreased epoch performance), knowledge of an upcoming switch was significantly associated with greater fatigue (higher subsequent rest times) (Figure 1). This indicates that the anticipation of a task switch intensified cognitive fatigue specifically during low-efficacy periods, with a negligible relationship during higher-efficacy epochs.

Next, using a logistic mixed effects model to predict performance, we found that switching tasks after a low-efficacy epoch was associated with significantly better performance (Figure 2). However, requiring subjects to switch tasks after a high-efficacy epoch significantly degraded subsequent performance. This critical finding demonstrates that the effects of task switching on subsequent performance are contingent on the efficacy state a subject is in prior to the switch: beneficial when efficacy is low but detrimental when efficacy is high.

These results demonstrate the nuanced relationship between task switching and cognitive fatigue, as well as its interaction with task efficacy states. Our findings suggest that task switching may attenuate cognitive fatigue associated with poor efficacy. Simultaneously, however, our results show that anticipating a task switch when a subject is already performing poorly may actually contribute to greater experienced cognitive fatigue. Future work will include replication with a larger pre-registered sample, development of computational models to understand task-switching decision processes, and explicit validation of SPR as an objective fatigue measure.

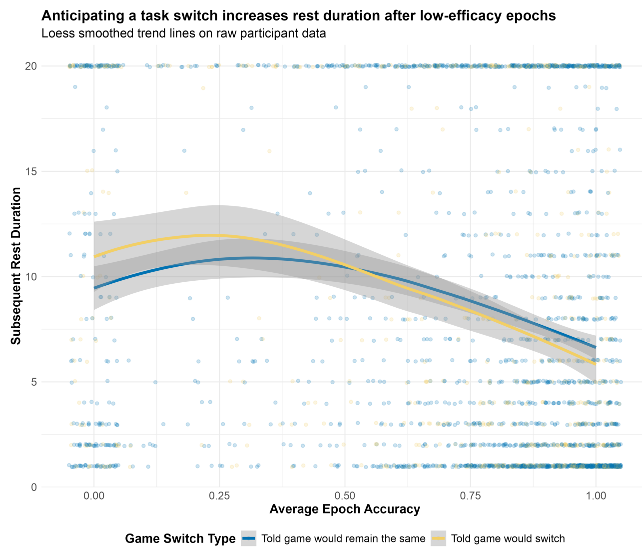


Figure 1: A visualization of the influence of task efficacy on cognitive fatigue. During low-efficacy epochs, the knowledge of an upcoming switch significantly increases the willingness to expend money to continue rest; this effect is not observed in higher efficacy epochs. Importantly, LOESS smoothing is used here for visualization but all statistical tests were done using a negative-binomial mixed effects model accounting for subject differences.

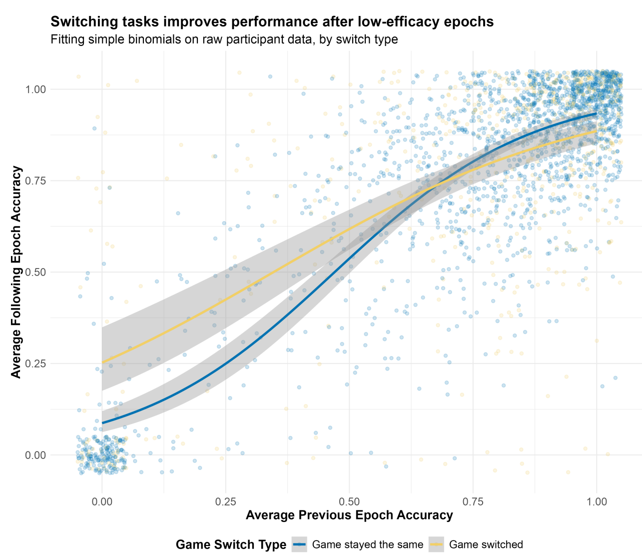


Figure 2: A visualization of the interaction between switching tasks and prior efficacy state on subsequent task performance. In low-efficacy epochs, undergoing a task switch is significantly beneficial to subsequent task performance. However when in a high-efficacy epoch, requiring subjects to task switch is associated with significant impairment in subsequent task performance. All statistical tests were done using mixed effects models accounting for subject differences.

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