Title
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Abstract

The *law of least mental effort* suggests that humans seek to minimize cognitive effort exertion. It is thought that we do so because effort is inherently aversive, playing the cost function in a cost-benefit analysis. However, this is not always the case: Some human activities are valued precisely *because* they are effortful. This dual nature of effort as valued and costly is known as the Effort Paradox. The question is therefore: what features differentiate an aversively effortful task from a valued one? In the current study, we explore how perceived progress might be one of these features. Across two experiments, we demonstrate that people willfully choose to engage in more demanding cognitive tasks when doing so yields telegraphed progress information. These results suggest that perceived progress may play a moderating role in cognitive effort aversion and hints at the possibility that progress itself may be an inherently valuable stimulus.

Keywords: Cognitive effort, Progress, Effort Paradox, decision-making, metacognition

Background

Cognitive effort is a ubiquitous phenomenon in decision-making. The quality and consistency of the decisions we make are highly related to how much effort we invest into making them (Kahneman, 2011). Though omnipresent in our daily lives, this process of exerting cognitive effort in the service of goal-directed behaviour is often theorized to be an inherently aversive experience. Indeed, the dominant view of cognitive effort posits that effort is a costly resource that people avoid spending when possible (Westbrooke & Braver, 2015). For instance, Kool et al. (2010) showed that, when presented with the choice, people consistently chose tasks that require less mental effort over those that are more mentally taxing. Other work has suggested that this aversion to hard mental work is even represented at the neurobiological level: Effort signals are tracked by the anterior cingulate cortex and are associated with aversiveness (Shenhav et al., 2017; Sayali & Badre, 2019). This view is so pervasive in the literature that it has been dubbed the *law of least mental effort* (Patzelt et al., 2019).

Still, it is clear that people do not prefer, in all circumstances, the course of least mental effort. Evidence of effort adding value to actions is perhaps just as prevalent as instances of effort being costly (Inzlicht et al., 2018). That is, there are a variety of activities that humans engage in precisely *because* they are effortful, and not in spite of the effort they require. At the trait level, differences in the degree to which people place intrinsic value in cognitive effort—a construct known as Need for Cognition—has been found to affect reward-induced adjustments in cognitive control, suggesting that the costs of effort are variable from individual to individual (Sandra & Otto, 2018). Similarly, the context of effort exertion can impact its valence. For instance, past work has shown that people value IKEA furniture more when they build it themselves, rather than when it comes ready-made (Norton, Mochon, & Ariely, 2012). In the realm of physical effort, mountain-climbers enjoy mountain-climbing due to its extreme physical and mental challenge, not despite it (Loewenstein, 1999). Indeed, the popularity of challenging games like Chess alone pose a problem for an account of cognitive effort that starts and ends with the view that effort is wholly aversive. These examples make clear that the effect effort plays on decision-making is contextual: sometimes discouraging action and other times invigorating it (Inzlicht et al., 2018).

What remains unclear, however, is whether contexts in which effort adds value are united by any common features. That is, can there be a feature that, when present, makes an effortful task more valuable than it would be if that feature were not present? In mountain-climbing and furniture building, for instance, one such feature is progress: people may be motivated to engage in these effortful tasks because they convey an acute sense of progress.

Recent work has shown that, by providing feedback on one's progress in a cognitively demanding task, performance improves (Katzir et al., 2020). Katzir et al. interpret this finding to suggest that people invest additional effort into a task when they feel that their effort is progressing them forward. If we consider this finding in the framework of an effort-reward tradeoff, an intuitive interpretation might be that effort is invested in these tasks not *despite* its inherent costs, but *because* participants' valuation of effort has shifted when its contribution to progress is clearly conveyed. To frame this as a question: Do people invest more effort when progress feedback is present *even though* it is difficult or *because* the effort itself is being perceived as valuable? In other words, the central question this study attempts to answer: Are people more willing to engage in cognitively demanding activities when effort explicitly confers progress?

To answer this question, we conducted two experiments. Experiment 1 was a preregistered online study (https://osf.io/gfrsh). Experiment 2 is a follow-up study meant to address the limitations of the between-subjects design of Experiment 1.

Experiment 1

Method

Progress-Modified DST. To test whether progress affected individuals' evaluation of effort, we used a modified version of the Demand Selection Task (DST; Kool et al, 2010; Patzelt et al., 2019) that incorporated progress feedback. This task consisted of two phases: a choice and judgement phase. In the judgement phase, participants had to judge a numeric digit that appeared on the screen (hereafter, the probe). This probe was one of two colours: green or orange. If the probe was green, participants were asked to make a magnitude judgment: whether the numeric probe was greater or smaller than 5. If the probe was orange, participants were asked to make a parity judgment: whether the number was even or odd. In isolation, these tasks are not exceptionally demanding. However, when interleaved on a trial-by-trial basis, the task becomes significantly more demanding, resulting in slower and more error-prone responding when the the task rules switch (e.g., magnitude on trial t, parity on trial t+1) to when they stay the same (Monsell, 2003). Participants practiced these tasks in isolation and combined at the beginning of the task for a total of 40 trials (10 green probes; 10 orange cues; 20 combined). These practice trials were not analysed.

Because the level of demand in this task is dependent upon the rate at which the rules switch, we were able to measure participants' demand preference by asking them to select between (learned) switch rates. To frame this in the context of the task, before completing each switch task, participants chose one of two "portals" (one blue and one purple; see Figure 1). Participants were told that these portals lead to different "worlds", in which the switch task differed slightly from each other. However, they were not explicitly told how the tasks differ between worlds. Depending on their choice, they completed either a low-demand or high-demand version of the task-switching paradigm described above. The low-demand version of the task-switching paradigm had a switch rate of 10%, whereas the high-demand version has a switch rate of 90%. While participants learned this portal-to-demand mapping from earlier practice trials, they were never explicitly told that one choice lead to an easier task and one to a harder one. Critically, this difficulty manipulation has previously been shown to elicit slower reaction times and poorer accuracy in the high-demand version of the task (i.e., more effort; Kool et al., 2010; Patzelt et al., 2019).

To manipulate progress, different groups of participants were randomly assigned to two versions of the DST

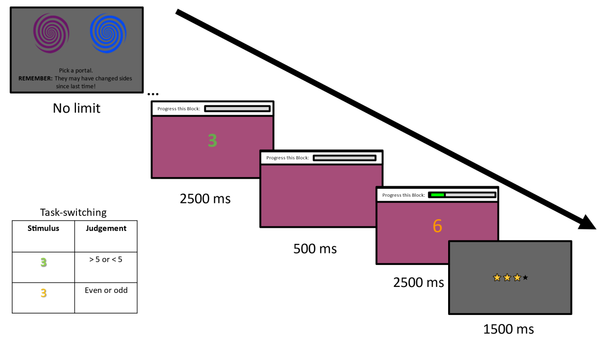

Figure 1. Task design in Experiment 1.

(between-subjects). One group completed a version of the task with progress feedback and another completed a version without progress feedback. Following Katzir et al., (2020), participants in the Progress condition received within- and between-block feedback. Within each block, participants were presented with a green bar at the top of the screen that indicated how much progress they had made during that block (i.e., the bar was 50% full when a participant completed half of the trials that block).

Between blocks, participants were shown a screen indicating how much progress they had made through the entire task. This screen consisted of 4 stars, one being filled in for each block the participant had completed thus far, presented for 1500 ms. In the No-Progress condition, the main task was the same, but participants did not receive any indication of progress.

The main task consisted of 300 trials, divided into 4 blocks of 75 trials. Once a response was made, a blank interstimulus interval appeared for 500 ms prior to the next probe appearing. If no response was made, the trial timed out and the task continued.

NASA Task-Load Index (NASA-TLX). We also collected data on how effortful participants found the modified-DST using the NASA-TLX (Hart, 2006). The NASA-TLX is a 7-item questionnaire that assesses the degree to which individuals found a task effortful (all questions rated on a continuous scale).

Exit Questionnaire. After participants completed the experiment and questionnaires, they were asked to fill out a short exit questionnaire that was meant to assess their subjective experience of the task, as well as basic demographic information. The following questions were asked in the exit questionnaire: (1) For statistical purposes, how old are you?; (2) For statistical purposes, what is your gender?; (3) Were the instructions clear to you? Did you notice anything particular about the task you'd like to comment on?; (4) When choosing between the portals, did you develop a preference for choosing one over the other?; (5) Did you notice a difference between the tasks in each portals? If so, what was it?; (6) Did you find the task more difficult in one portal than the other?

Participants. We collected data from 502 participants on Amazon Mechanical Turk. An *a priori* power analysis revealed that this was sufficient to detect an effect size of minimal interest at 80% power. However, after applying preregistered exclusion criteria, our sample dropped down to 386 participants (M_{age} = 37.80; s_{age} = 11.40, 69% male). This is the sample we use for the following analyses. We address the potentially large exclusion rate in the discussion below.

Results

Manipulation Checks. In order to determine whether our demand manipulation was successful, we modeled both objective (reaction time (RT) and accuracy) and subjective (NASA-TLX ratings) measures of demand.

First, using linear and binomial multilevel models respectively, we found that participants were significantly slower (b = 173.85, CI = [709.68–860.38], $p < .001$) and less accurate (OR = 0.78, CI = [0.74–0.83], $p < .001$) in high switch rate blocks compared to low switch rate blocks. We did not find a significant effect of condition on RT or accuracy (ps > .05), but did find a small interaction between condition and accuracy (OR = 0.89, CI = [0.83–0.96], p = 0.003), such that participants in the progress condition suffered slightly fewer switch costs than those in the no progress condition (~2% difference). At the trial-level, we also found that switch trials incurred slower (b = 195.59, CI =[189.41–201.76], $p < .001$) and less accurate (b = 0.73, CI =[0.69–0.77], $p < .001$) responding. We did not find a significant effect of condition, nor an interaction between condition on accuracy (ps > .05).

Second, we found that participants experienced high switch rate blocks as more cognitively effortful than low switch rate blocks. During high switch rate blocks, participants felt as though the task was more effortful (b = 0.35, $p < .001$), mentally taxing (b = 0.23, p = .0132), harder to perform (b = -0.19, p = .0320), and rushed (b = 0.24, p = .0252) than during the low demanding block. The only dimension measured by the NASA-TLX for which there was no difference between demand levels was frustration (b = 0.03, p = .836). These ratings did not differ between condition, nor did condition interact with demand level (all ps > .45).

Choice Data. The main hypothesis of this experiment was that participants in the Progress condition would be more often willing to engage in the high demand switch task than those in the No Progress condition. To test this hypothesis, we used a mixed-effects logistic regression, predicting demand selection by condition with a random intercept per participant.

As summarized in Figure 2, we found that participants in the No Progress condition selected the high demand task significantly less than chance (OR = 0.79, CI = [0.68– 0.91], p = 0.002). Participants in the Progress condition on the other hand were indifferent to demand level (OR = 0.99, CI = [0.86 – 1.14], p = 0.888).

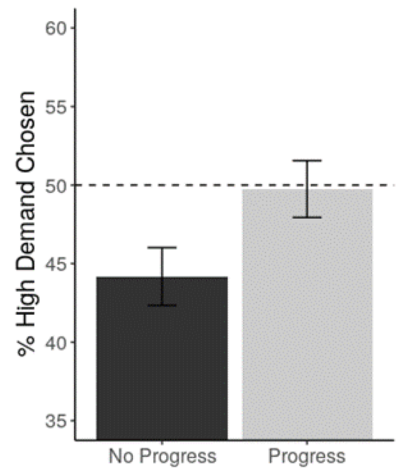

Figure 2. Demand preference across progress conditions in Experiment 1.

In short, the odds that participants in the Progress condition chose the high demand option was 1.25 times that of those in the No Progress condition (OR = 1.25, CI = [1.02 – 1.54], p = 0.03): a small, but significant, difference.

Discussion

In experiment 1, we sought to test whether providing participants with feedback about their progress would moderate their demand preferences in a variant of a well-established demand selection paradigm. We seem to find modest support for this conclusion in the current sample,

such that participants in the Progress condition were more often willing to complete the high demand switch task than those in the No Progress condition. Notably, they did so despite the fact that we observed no signs of objective or subjective demand decreases between conditions. Thus, it seems that these participants were willingly choosing to complete a task that was more cognitively demanding, simply because they had a sense of their progress in the task.

While an important first result, this experiment suffered from a number of limitations that hinders its explanatory power. First, the results we obtained were rather subtle, never amounting to more than indifference between high and low demand in the Progress condition. This is likely due to the nature of the experimental set up, which tested participants in a between-subjects fashion on a high number of switch trials with few choice trials (4). Combined with the fact that it is unlikely many participants would solely choose one portal for all choices (effectively creating a floor and ceiling effect), a more subtle, within-subjects, design is likely needed to understand these effects. Relatedly, our selective exclusion criteria reduced our sample size, which while large, could be under-powered to detect minimally interesting effect sizes in future replications. Most importantly, while the current results showcase an important descriptive difference between effort preference when progress is present versus when it is not, they do not address *how* progress modulates demand preference. That is, it remains unclear how perceived progress affects metacognitive cost-benefit analyses when it comes to explicit effort-related decisions: Does it dampen effort costs, or is progress perhaps adding value, thus offsetting effort costs?

To address these limitations, we conducted a second experiment in which we tested participants' willingness to explicitly trade-off effort for progress information in a within-subjects design.

Experiment 2

Method

The between-subjects design of Experiment 1 limited its explanatory power. Namely, it only allowed us to find a descriptive difference between groups (in a particularly large sample) but did not allow for us to robustly explore how participants incorporated progress information into their effort-related decisions. To improve our understanding of progress' role in demand selection, we designed a within-subject variant of the DST following a design used by Sayalı and Badre (2019) to study demand-avoidant choice (preregistered at https://osf.io/2vcbk). The main goal of this design was to test whether participants would explicitly trade higher demand for progress information.

As in Experiment 1, Experiment 2 had two phases: a choice and judgement phase. In the choice phase, participants were presented with two of six decks to choose from (2000 ms). Each deck corresponded to a switch rate that participants would have to complete in the subsequent judgement phase. The three possible switch rates were 10%, 50%, and 90%. In the judgement phase, participants completed the same switch task as in Experiment 1, wherein the rules (magnitude/parity) switched at a rate associated with the deck participants chose. Notably, half of these decks were paired with progress feedback and half were not. When a progress deck was chosen, participants received within-block progress feedback on the subsequent switch task (i.e., a green bar filled following each choice; see Figure 3a).

As a result of this design, there were six total decks participants could choose from, varying according to their associated switch rate and whether or not they produced progress feedback (see Figure 3b). Participants learned these pairings during a Learning Phase, during which participants learned the basics of the switch task, and were shown the switch task after choosing each deck. Overall, participants were exposed to 15 unique possible deck pairings, each presented 4 times.

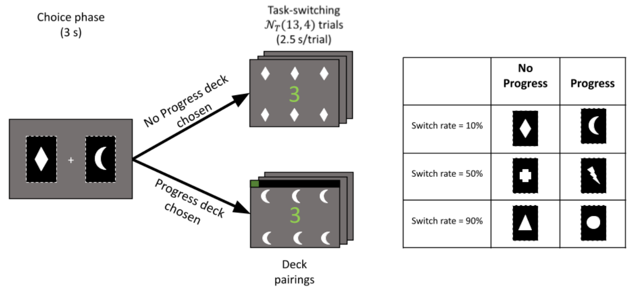

Figure 3. Task design in Experiment 2.

complete runs of the task each participant must complete. These 15 pairings were fully counterbalanced, allowing for conclusions to be drawn about participants' pure effort preferences (when progress was held constant across decks), pure progress preferences (when demand was held constant across decks), and the interaction between the two. Each switch task varied in length according to a predefined truncated normal distribution ranging from 8 trials to 22 trials, with a mean of 13. This made for a total of 60 explicit effort/progress decisions and approximately 780 switch task trial per participant.

Participants. We collected data from 107 participants on Amazon Mechanical Turk. After applying preregistered exclusion criteria, 67 participants were included in the final analysis (M_{age} = 36.98, s_{age} = 9.67, 61% male).

Results

Manipulation Checks. As in experiment 1, we analysed RT and accuracy to determine whether our demand manipulation was successful, using linear and binomial multilevel models respectively. We expected to replicate the overall switch cost results found in Experiment 1 and furthermore observe a monotonic relationship between overall deck switch cost and RT and accuracy (increasing and decreasing, respectively).

These predictions were supported in the current sample. Namely, we found that participants responded more slowly (b = 194.88, CI = [189.28–200.49], $p < .001$) and less accurately (OR = 0.61, CI = [0.57–0.66], $p < .001$) on switch trials compared to repeat trials. We also found a significant main effect of progress on accuracy, such that responses when progress feedback was present were slightly more accurate than when it was not (OR = 1.09, CI = [1.01–1.17], p = .0248).

Choice Data. Our main predictions for Experiment 2 centered on participants' choice behaviour. These data are summarised in Figure 4. Overall, we found that participants' were effort avoidant (OR = 0.69, CI = [0.61–0.78], $p < .001$) and progress-seeking (OR = 1.34, CI = [1.21–1.48], $p < .001$).

As a general manipulation check for the effect of switch rate on effort avoidance, we predicted that participants would choose the low demand deck in pairings where progress was held constant—that is, when participant could not trade-off demand for the presence or absence of progress feedback because both decks to choose from on a trial shared the same progress condition (progress or no-progress). Using a logistic mixed-effects regression, we found marginal support for this hypothesis in the current sample, such that participants either chose the low effort deck or were indifferent to demand pairing (see Figure 4a). Both in pairings in where both decks yielded progress (OR = 0.57, CI =[0.47–0.68], $p < .001$) and neither deck yielded progress (OR = 0.78, CI = [0.65–0.93], $p = 0.007$), participants' were significantly effort averse (i.e., avoided demand more than chance level), according to Wald z-tests from mixed-effects logistic regression.

Our second prediction was that participants would choose the deck that yielded progress feedback when effort was held constant. We found support for this hypothesis, such that participants preferred progress decks to no progress decks when demand was held constant (OR = 1.65, CI = [1.35 – 2.02], $p < .001$; see Figure 4b). More precisely, participants significantly sought progress information in ⅔ of the deck pairings where demand was held constant—10% vs. 10% (OR = 1.79, CI = [1.32–2.42], $p < .001$) and 50% vs. 50% (OR = 2.09, CI = [1.54–2.85], $p < .001$)—and numerically so in the 90% vs. 90% pairing (OR = 1.22, CI = [0.91–1.63], $p = .1870$; Figure 4c).

Our third prediction was that, when choosing between decks that vary both in terms of demand and progress feedback, participants would choose the high effort deck when it conveyed progress, but would choose the low demand deck when it did not. Critically, we found support for this hypothesis, such that participants were statistically indifferent to demand, and even showed a trend towards demand-seeking behaviour, when progress was associated with the high demand option (OR = 1.17, CI =[0.98–1.41], $p = .084$). Conversely, when progress came at a lower cognitive cost, participants overwhelmingly avoided the high demand, no-progress, option (OR = 0.42, CI = [0.34–0.51], $p < .001$; Figure 4d). These results support those found in Experiment 1, but also demonstrate that participants were willing to incur greater cognitive costs in *exchange* for progress information.

Discussion

The goal of Experiment 2 was to improve on the design of Experiment 1 in order to increase its explanatory and statistical power. Our results indicate that we succeeded in this regard and point to interesting interpretations that the results of Experiment 1 alone could not support, which we discuss in the next section.

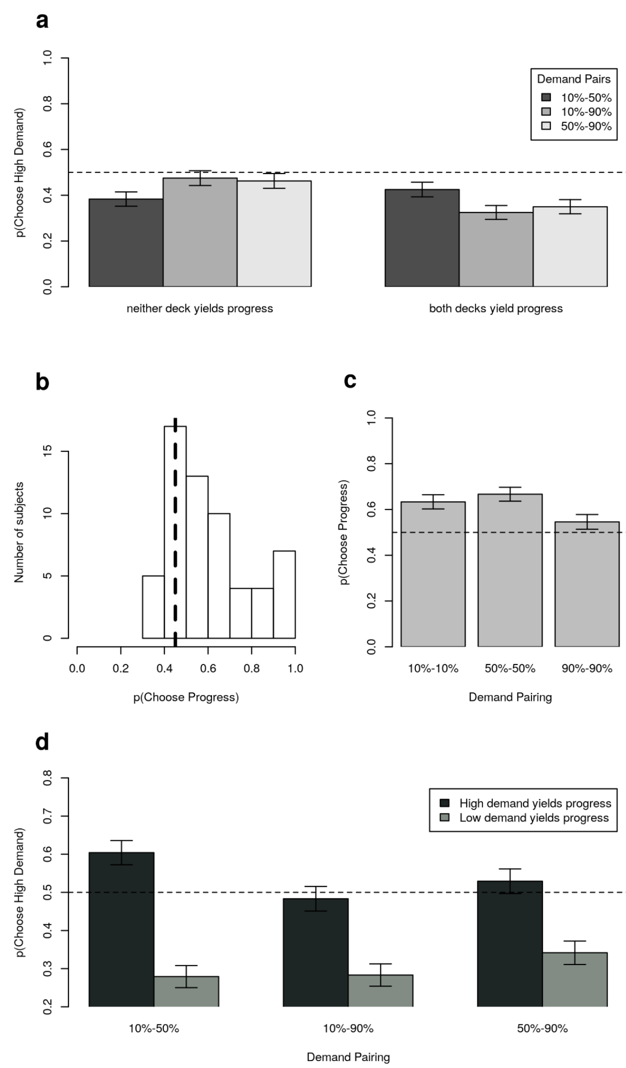

Figure 4. Proportion of (a, d) high demand decks and (b, c) progress decks selected across demand and progress pairings.

General Discussion

In the current study, we sought to explore whether perceived progress moderated cognitive effort aversion. We conducted two experiments and in both found evidence that people were willing to engage in harder mental work if it was accompanied by information about their progress in a task. This was true even when participants explicitly had the option of working less hard without incurring any additional consequences.

Why might progress moderate demand selection? Classical work by behaviorists has shown that animals modulate effort investment in accordance with perceived progress in simple reinforcement learning tasks (Hull, 1932; Miller, 1944). These early results laid the groundwork for the goal-gradient hypothesis, which proposed that organisms exert more effort as they approach a goal (Hull, 1932).

This idea has received newfound attention in the consumer behaviour literature, as it is capable of explaining a spate of findings that show that consumers are more willing to engage with products when they feel they are nearing some kind of reward (Kivetz, Urminsky, & Zheng, 2006). Under this updated computational view of the goal-gradient hypothesis, progress offsets effort costs by increasing an agent's motivation to achieve their goal. Considered from the perspective of cognitive effort research, this would suggest that progress information carries inherent value that, when weighed against the inherent costs of effort, tilts the cost-benefit analysis in favour of effort investment. This view fits well with our results from Experiment 2, in which we observe that people largely preferred decks that conveyed progress to those that did not when effort was held constant, suggesting that progress carried some additional value. The argument that progress carries inherent value is also supported by neurobiological evidence. Monkey research led by Shidara (Inaba et al., 2013; Shidara, Aigner, & Richmond, 1998) has suggested that progress information and reward are processed by the same brain areas, namely the dorsal raphe nucleus and the ventral striatum. To speculate, this might suggest that reward and progress share a similar representation at the neural level, which, if true, would provide a physiological foundation for progress' inherent value.

If progress information does carry inherent value, it may have important implications for our understanding of the Effort Paradox. Namely, it might suggest that, in circumstances where it seems effort is *adding* value (i.e., the Effort Paradox; Inzlicht et al., 2018), the actual *costs* of effort may be masked by other valuable stimuli in the environment. Importantly, these stimuli may be those that have yet to be considered to carry value for human decision-makers. For example, in a task where people could trade future rewards for non-instrumental information—i.e., information which bears no impact on reward—Bennett and colleagues (2016) found that people inherently valued information and were willing to incur financial costs to acquire it. In addition to information, there may exist a panoply of other stimuli that carry inherent value for humans, which can offset both financial and cognitive costs. Left unexplored, these unmeasured values may shift human effort investment, creating the illusion of an Effort Paradox where one, in some cases, may not exist. This issue is complicated further when the stimuli adding value is inherently linked to the task being performed, as is the case for progress. Therefore, future research should focus on determining whether activities in which effort seems to be adding value can be explained by potential alternative sources of value that exist in the environment. In the current study, we provide evidence that progress information may be one such value-adding stimulus.

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