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Cognitive Psychology

Effort Expenditure Decreases Risk Aversion When Dealing With Gains but Not Losses

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Separate lines of research suggest that people tend to avoid mental effort, but also value it. Evidence for this effort paradox in the same context is scarce. We tested whether people discount effort *prior* to the investment of effort and value effort *following* its investment. In three preregistered experiments (total $N = 450$), participants repeatedly chose between executing a low-effort task for a small reward and a high-effort task for a larger reward. Participants then chose whether or not to gamble with their rewards. As people tend to become more risk averse as subjective value increases, we reasoned participants would be less likely to gamble with rewards the harder they had to work for them. In Studies 1 and 2, we framed the experiment in terms of gaining rewards. In Study 3, we framed the experiment in terms of losing rewards. In all three studies, effort was discounted prospectively, meaning people demanded higher rewards to invest more effort. Contrary to our predictions, we found that people were more likely to gamble with the rewards the more effort it required to obtain them, but only when the rewards were framed in terms of gains (Studies 1 and 2). Collectively, these results suggest that any potential effort paradox is unlikely to occur when people are aware of the association between investing effort and gaining rewards. Our results also imply a novel hypothesis, namely that the aversive feeling accompanying effort might motivate people to engage in risky behavior.

Introduction

In everyday life, people often have to invest mental effort to achieve their goals. People might have the ability to perform a given task successfully, but may fail to do so because they are not willing to invest the necessary amount of mental effort (Kurzban et al., 2013). Thus, effort is the process that mediates the extent to which an activity is performed relative to how well it could theoretically be performed (Shenhav et al., 2017), and as a consequence is critical for people to align their behavior with their goals in a wide variety of contexts such as learning, eating healthy, and regulating emotions (Hofmann et al., 2012). Whereas a lot of recent research has attempted to understand the costs associated with effort (e.g., Kool & Botvinick, 2018; Lockwood et al., 2021; Shenhav et al., 2017), effort can also add value (Inzlicht et al., 2018). In this paper, we experimentally investigated this so-called 'effort paradox' (i.e., the phenomenon that effort's value might be deflated prospectively and inflated retrospectively).

Very generally, people tend to dislike the aversive feeling that accompanies effort expenditure (Bijleveld, 2018; Dreisbach & Fischer, 2015; Saunders et al., 2015) and avoid it when possible. The law of least work states that when given a choice between similarly rewarding options, people learn to avoid those options that require more work or effort (Hull, 1943), and this law indeed seems to hold most of the time. For example, when given the choice to invest more or less effort for the same reward, people almost always choose the easier option (Cameron et al., 2019; Kool et al., 2010; but see also Wu et al., 2023). Similarly, people are often willing to accept a smaller reward to avoid effort (Apps et al., 2015; Westbrook et al., 2013). This tendency is called effort discounting; people discount rewards by the amount of effort required to obtain them. Finally, people's willingness to invest further effort tends to decrease quickly as a function of the amount of effort recently invested (Dora et al., 2022).

Paradoxically, it seems that effort can also be valued (Inzlicht et al., 2018). For example, multiple studies have

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shown that people assign higher (monetary) value to things they invested effort in (Norton et al., 2012), and are subsequently less likely to share them (Muehlbacher & Kirchler, 2009). Similarly, early work on cognitive dissonance indicated that people assign more value to things they had to work for (Cooper, 2007; Festinger, 1957), and people who had to work to gain entry into a group subsequently evaluated the group more favorably (Aronson & Mills, 1959). At this point, however, the evidence for this effort paradox mainly comes from two separate lines of research. One line of research shows that people *prospectively* devalue and discount effort, another line shows that people *retroactively* value effort or the products tied to it. As such, research has rarely explored whether the investment of effort in the context of the same activity can be considered both costly and valued within seconds of one another (and thus near-concurrently), which we would consider truly paradoxical.

Recognizing and exploring effort's potential value next to its well-established costs is crucial to develop ways in which cognitive scientists might help people to engage in mentally effortful activity over a prolonged period of time. This might enable people to more comfortably reach their personal goals, for example in the context of schoolwork, work tasks, or emotion regulation (Dora et al., 2021; Galla & Duckworth, 2015; Hofmann et al., 2012). If we understand how we can promote positive associations with the investment of effort – for example noting effort's association with meaning and purpose (Inzlicht & Campbell, 2022), we might be able to develop strong habits of effortful activity (Eisenberger, 1992), an idea we are working on in a separate project (Lin et al., in press). To this end, we are wondering whether the effort paradox can be observed within seconds prior to and following the exertion of mental effort.

The Present Study

Here, we aim to provide such a test in an experimental setting. In three studies, we test whether people discount effort immediately prior to a demanding task and value effort immediately following the demanding task. To test these hypotheses, we first presented participants with an effort discounting task inspired by previous research (Apps et al., 2015). Participants had to choose between a low-effort task for a fixed, small reward or a high-effort task for a larger reward (four effort levels, four reward levels, fully crossed). With this task, we tested whether participants discount effort prospectively, which would imply that participants are more willing to choose the high-effort task if it is less effortful and more rewarded. After completing the choice task and performing the action at the chosen effort level, we gave participants the opportunity to gamble with the rewards they just received. As explained further below, with this task we attempted to test whether participants value effort retrospectively, as people tend to be more risk averse (i.e., less likely to gamble) for things they value more. We chose this implicit operationalization of value over a self-report to prevent participants from deliberately reporting back the rewards associated with the task to us and to measure an automatically activated cognition instead (de Houwer, 2006).

We decided to represent value via the willingness to gamble with the reward for one's efforts based on prospect theory (Kahneman & Tversky, 1979), which describes how people make decisions involving risk. All else being equal (e.g., the probability of each outcome occurring), the theory states that people tend to become more risk averse toward a good or product the higher they subjectively value that good. So, the more a person likes a t-shirt or coffee mug, the fewer risks they are willing to take with these objects. Prospect theory further proposes that people evaluate gains and losses differently, with people assigning higher value to avoiding losses compared to gaining rewards. More than 30 years after being proposed, prospect theory is supported by a large body of behavioral economic work (Ruggeri et al., 2020), and continues to be viewed as the best description of people's evaluation of risk (Barberis, 2013). Thus, we a priori interpret a lower tendency to gamble with rewards at increasing levels of effort as evidence that the effort which had just been discounted less than a minute ago is now being valued. In the context of prospect theory, 'rewards' could be conceptualized as either *gaining* rewards or *avoiding losing* them.

We tested prospective effort devaluation and retrospective effort valuation with two separate sets of hypotheses. In the discounting task, participants had to choose whether to perform a set of low-effort calculations (adding 0 to three consecutive digits) for a low reward of 1 credit or to perform a set of high-effort calculations (adding 1 or 3 or 5 or 7 to three consecutive digits and choosing the correct solution) for a higher reward of 2 or 4 or 6 or 10 credits (fully crossed; Depow et al., 2022). They also self-reported how much effort the set of trials required. Following earlier research (Apps et al., 2015), we hypothesized that participants would display an effort discounting effect, whereby effort level during the choice task would relate to effort choice, so that the more effortful option is less likely to be selected the more effort it requires (Hypothesis 1a); and whereby the reward level during the choice task would relate to effort choice, so that the more effortful option is more likely to be selected the more it is rewarded (Hypothesis 1b). Then, participants were asked whether or not to gamble with the rewards they just received. To test whether participants value effort retrospectively, we tested whether participants become more risk averse when they worked harder for a reward. We hypothesized that effort level during the choice task will relate to subsequent gambling choice, such that the higher the effort in the choice task, the less participants will be willing to make the risky gamble with earnings from that task (Hypothesis 2a) and that subjective effort relates to subsequent gambling choice, such that the more effortful a task is perceived, the less risk participants will be willing to take (Hypothesis 2b).

Study 1

Study 1 tested our predictions in the context of *gaining* rewards. We preregistered and ran one study prior to Study 1 reported in this paper. In this initial study, the effort manipulation failed as indicated by self-reported effort across the difficulty levels of the math task (M_{add1} = 43.6, M_{add3} = 47.3, M_{add5} = 47.4, M_{add7} = 42.5). We expected that adding larger numbers would require more effort from participants (Depow et al., 2022). As this was not sufficient, we decided to alter the manipulation after this initial study by additionally decreasing the time stimuli were presented at higher effort levels. We decided not to report the results of the initial study here, as it does not provide a stringent test of our hypotheses given the failure of our effort manipulation (but the data of this study are also available at https://osf.io/cqxfk/).

Method

Preregistration and Data Availability

We preregistered design, hypotheses, sample size, and statistical analyses. Our preregistration, data, power simulation and analysis scripts are available on the Open Science Framework project of this article (https://osf.io/cqxfk/). All decisions described hereafter were preregistered unless noted otherwise.

Sample Size Rationale

We ran a set of power simulations (N = 1,000) using the simr package in R (Green & Macleod, 2016). For our focal Hypothesis 2a we assumed that the probability to gamble decreases by 10% per effort level. We then went on to simulate power for the decrease in one effort level. According to these assumptions, we would achieve power = .98 with N = 123. To account for the possibility that the manipulation and hence the effect would be slightly weaker, we aimed for 150 participants in each study.

Participants, Procedure, and Design

150 undergraduate students (M_{age} = 19.09, 109 females) recruited via the University of Toronto Scarborough's participant pool participated in exchange for course credit and a variable cash payment depending on the choices made in the experiment. We excluded one participant in who failed two attention checks. We excluded one additional participant who never chose the high-effort option in the choice task. After providing informed consent, participants reported demographics (age & gender), received instructions, and practiced the experimental task (first two blocks of the math task, then two blocks including the demand selection choice, and finally two blocks including self-reports and gambling choice). Participants then completed 32 blocks of this experimental task (described below). In total, the experiment took approximately 30 minutes to complete. We employed a within-subjects design (four effort levels, four reward levels) with repeated measures of demand selection choice, self-reported effort, and gambling choice. The study procedures were reviewed and approved by the University of Toronto Institutional Review Board.

Experimental Task

The experimental task is visualized in Figure 1.

Choice task. First, in each experimental block, participants were presented with the choice between executing a low-effort task for a fixed, small reward or a high-effort task for a variable, larger reward. The low-effort task consisted of adding 0 to each of a sequence of three digits presented in the center of the screen (one at a time), and subsequently choosing the correct answer among two three-digit sequences presented side by side. Digits in the add-0 task were presented for 400ms each. The low-effort task always awarded the participant with one credit (credits earned were translated to monetary rewards at the end of the experiment). The high-effort task considered of adding 1 (digits presented for 400ms at a time), 3 (350ms), 5 (300ms), or 7 (250ms) to each of a sequence of three digits, and subsequently choosing the correct answer among two three-digit sequences. The reward associated with the high-effort task varied (2, 4, 6, 10 credits). Each combination of effort and reward levels were presented twice to each participant for a total of 32 experimental trials. Second, after choosing for either the low-effort or high-effort option, participants completed five trials of the math task at the chosen demand level. Participants were informed that they would receive the credits associated with their chosen option if they performed the calculations correctly at least 90% of the time. These credits were later converted to monetary rewards.

Self-reported effort. Third, participants reported the amount of effort it took them to perform the math task for the past five calculations ("How much effort did the past five calculations require?") on a Visual Analogue Scale (0 = "None at all" – 100 = "Very much").

Gambling choice. Fourth, participants were presented with the choice to gamble with the credits they just received for this experimental block. They could either choose to keep the earned credits with 100% certainty, or choose to take the risk to double the credits earned, which came at a 50% risk of losing the credits. Participants received no feedback during the experiment whether or not their gamble was successful.

Data Analysis

We conducted all of our analyses in R (version 4.3.1; R Core Team, 2021). We tested our hypotheses using a generalized linear mixed-effects modeling approach using the *glmer* function (*lme4* package; version 1.1-34; Bates et al., 2015). In all analyses, the experimental trial was the unit of analysis. We included a random intercept in all analyses to account for differences in effort discounting tendency and risk aversion between participants. We preregistered not to include a random slope in our models as such models did not converge in our pilot data.

To test Hypotheses 1a and 1b, we predicted choice (low-effort vs high-effort) in the choice task from effort level and reward level. For our tests of Hypotheses 2a and 2b, we excluded blocks where participants chose the low-effort option. To test Hypothesis 2a, we predicted gambling choice from effort level, controlling for reward level. To test Hy-

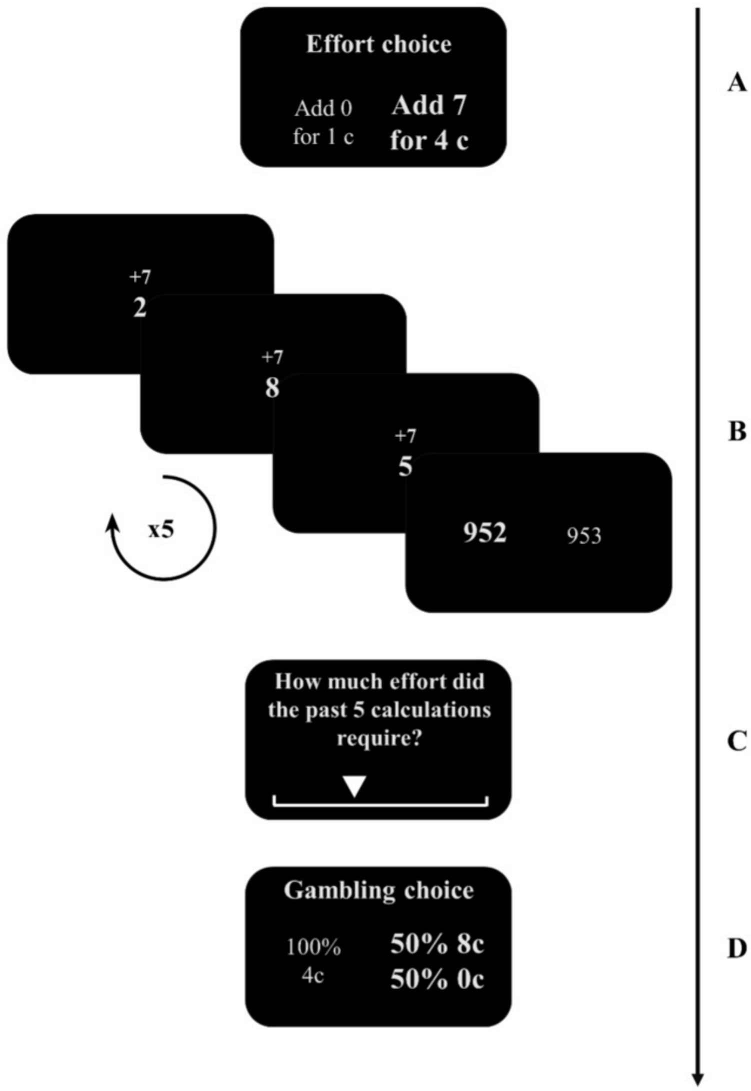

Figure 1. Sequence of events in the choice task. (A) An example of a choice between low-effort task for fixed small reward and high-effort task for larger reward. (B) An example of the high-effort task. Participants have to add 7 to three consecutive digits and then select the correct response. They performed five such calculations following each effort choice. (C) Participants self-report the amount of effort invested over the past 5 calculations. (D) Participants choose whether or not to gamble with the rewards received.

pothesis 2b, we predicted gambling choice from subjective effort ratings, controlling for reward level. To determine p-values, we computed Type III bootstrapped Likelihood Ratio tests (two-tailed; $\alpha = .05$) using the *mixed* function (*afex* package; version 1.3.0; Singmann et al., 2015).

Results

Participants chose the high-effort option in 72% of experimental blocks, and chose to gamble with the rewards 39% of experimental blocks. They reported increasing subjective effort at increasing effort levels ($M_{add1} = 32.4$; $M_{add3} = 49.6$; $M_{add5} = 54.9$; $M_{add7} = 66.4$, $p < .001$). We first fitted a model predicting effort choice from effort level and reward level. This model had a prediction accuracy of 85%, meaning it correctly predicted the choice for high or low effort on 85% of experimental blocks. We then fitted a model predicting gambling choice from effort level and reward level. This model had a prediction accuracy of 72%. Finally, we fitted a model predicting gambling choice from self-reported effort. This model also had a prediction accuracy of 72%. Results are summarized in Table 1 and visualized in Figure 2.

Hypothesis 1

We found evidence for the predicted pattern of effort discounting. Participants were *less* likely to choose the high-effort option the more effort it required (X^2 (3) = 718.04, $p < .001$), and were *more* likely to choose the high-effort option the more it was rewarded (X^2 (3) = 145.26, $p < .001$). Compared to the lowest effort level (add 1), participants were estimated to be 23.34 times (95% CI = [17.99, 30.88]) *less*

Table 1. Model results predicting the likelihood to choose the high-effort option (H1) and the likelihood to gamble (H2) in Study 1. The reference categories in both models are the lowest effort and reward level respectively. Model results need to be exponentiated to reflect odds ratios.

Hypothesis 1			
Fixed effects		Estimate	95% CI
	Intercept	2.39	2.01, 2.78
	Effort 3	-1.01	-1.30, -0.75
	Effort 5	-1.62	-1.92, -1.34
	Effort 7	-3.15	-3.43, -2.89
	Reward 4	0.55	0.32, 0.78
	Reward 6	0.84	0.62, 1.08
	Reward 10	1.43	1.18, 1.69
Random effects		Variance	SD
	Intercept	3.46	1.86
Hypothesis 2a			
Fixed effects		Estimate	95% CI
	Intercept	-0.61	-0.89, -0.33
	Effort 3	0.07	-0.15, 0.28
	Effort 5	0.28	0.07, 0.51
	Effort 7	0.29	0.06, 0.55
	Reward 4	-0.26	-0.49, -0.02
	Reward 6	-0.16	-0.37, 0.06
	Reward 10	-0.38	-0.60, -0.17
Random effects		Variance	SD
	Intercept	1.40	1.18
Hypothesis 2b			
Fixed effects		Estimate	95% CI
	Intercept	-0.47	-0.73, -0.22
	Effort self-report	0.07	-0.02, 0.14
Random effects		Variance	SD
	Intercept	1.43	1.20

likely to choose for the high-effort option at the highest effort level (add 7). Similarly, compared to the lowest reward level (2 credits), participants were estimated to be 4.18 times (95% CI = [3.25, 5.42]) *more* likely to choose for the high-effort option at the highest reward level (10 credits).

Hypothesis 2

Contrary to our prediction, we found that participants were *more* likely to gamble with the rewards the more effort it required to obtain them (X^2 (3) = 10.12, p = .019). Participants were estimated to be 34% (95% CI = [6%, 73]) *more* likely to gamble at the highest compared to the lowest effort level. Subjective reports of effort investment, however, did not predict gambling choice (X^2 (1) = 2.62, p = .126).

Discussion

Study 1 supported our prediction that effort is discounted prospectively (Apps et al., 2015; Westbrook et al., 2013). However, to our surprise participants displayed greater risk tolerance and were more willing to gamble with rewards after investing more effort. The fact that the subjective feeling of effort did not simultaneously predict the subsequent decision to gamble might reflect a cognitive process in which participant's aversion to effort increases over time, while the objective amount of effort required to perform the task remained stable throughout the experiment (Bijleveld, 2018; Dora et al., 2022; Hopstaken, 2015). This dissociation between objective effort demands and subjective effort ratings suggests that gambling behavior may have been driven by task demands rather than the phenomenology of effort. Such dissociations between objective and subjective effort are well-documented in the effort literature, with momentary experiences of effort often fluctuating over time while task demands remain stable (e.g., Bijleveld, 2018). Taken together, these results (if robust & replicable) would indicate very clearly that we would not observe the effort paradox in our experimental design. Given that the results were in the opposite direction to our

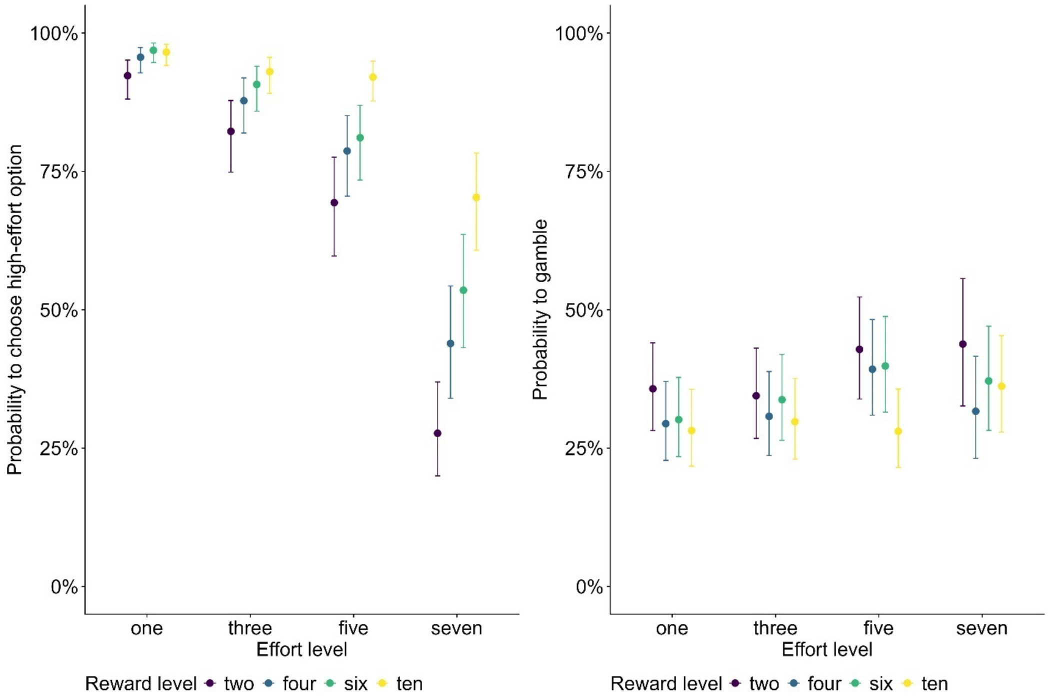

Figure 2. Predicted probabilities to choose for the high-effort option (left) and to choose to gamble with the rewards (right) as a function of effort and reward level in Study 1.

hypothesis and the lower bound of the confidence interval was close to zero, we decided to attempt to directly replicate this surprising finding.

Study 2

Study 2 was a direct replication of Study 1. While we initially planned and preregistered to once more sample undergraduate students via the University of Toronto Scarborough's participants pool, due to the COVID-19 pandemic, and the restrictions on in-person testing, we deviated from our preregistration to recruit the same undergraduate students but tested them online instead of in the lab.

Method

150 participants (M_{age} = 22.48, 43 females) recruited via Prolific (Palan & Schitter, 2018) participated in exchange for a base payment of £3.75 and a variable cash payment depending on the choices made in the experiment. We excluded one participant who never chose the high-effort option in the choice task. The procedure, experimental task, and data analysis were identical to Study 1.

Results

Participants chose the high-effort option in 76% of experimental blocks and chose to gamble with the rewards 33% of experimental blocks. They reported increasing subjective effort at increasing effort levels (M_{add1} = 30.9; M_{add3} = 47.1; M_{add5} = 57.9; M_{add7} = 71.5, p < .001). We first fitted a model predicting effort choice from effort level and reward level. This model had a prediction accuracy of 87%. We then fitted a model predicting gambling choice from effort level and reward level. This model had a prediction accuracy of 84%. Finally, we fitted a model predicting gambling choice from self-reported effort. This model also had a prediction accuracy of 84%. Results are summarized in Table 2 and visualized in Figure 3.

Hypothesis 1

We replicated the predicted pattern of effort discounting. Participants were *less* likely to choose the high-effort option the more effort it required (X^2 (3) = 702.92, p < .001), and were *more* likely to choose the high-effort option the more it was rewarded (X^2 (3) = 326.00, p < .001). Compared to the lowest effort level (add 1), participants were estimated to be 31.19 times (95% CI = [22.64, 43.38]; Figure 3a) *less* likely to choose for the high-effort option at the highest effort level (add 7). Similarly, compared to the lowest reward level (2 credits), participants were estimated to be 9.39 times (95% CI = [7.17, 12.68]) *more* likely to choose for the high-effort option at the highest reward level (10 credits).

Hypothesis 2

We also replicated the effect in the opposite direction to our second hypothesis. Once more, we found that participants were *more* likely to gamble with the rewards the more effort it required to obtain them (Study 2: X^2 (3) = 17.04, p < .001). Participants were estimated to be 57% (95% CI = [16%, 108%]) *more* likely to gamble at the highest compared to the lowest effort level. Also, subjective reports of effort investment again did not predict gambling choice (Study 2: X^2 (1) = 3.51, p = .058).

Table 2. Model results predicting the likelihood to choose the high-effort option (H1) and the likelihood to gamble (H2) in Study 2. The reference categories in both models are the lowest effort and reward level respectively. Model results need to be exponentiated to reflect odds ratios.

Hypothesis 1			
Fixed effects		Estimate	95% CI
	Intercept	2.56	2.15, 2.99
	Effort 3	-1.22	-1.51, -0.92
	Effort 5	-1.96	-2.27, -1.66
	Effort 7	-3.44	-3.77, -3.12
	Reward 4	1.04	0.80, 1.28
	Reward 6	1.61	1.34, 1.87
	Reward 10	2.24	1.97, 2.54
Random effects		Variance	SD
	Intercept	3.89	1.97
Hypothesis 2a			
Fixed effects		Estimate	95% CI
	Intercept	-0.76	-1.23, -0.29
	Effort 3	-0.05	-0.32, 0.21
	Effort 5	0.33	0.06, 0.59
	Effort 7	0.45	0.15, 0.73
	Reward 4	-0.59	-0.87, -0.32
	Reward 6	-1.31	-1.61, -1.04
	Reward 10	-1.53	-1.83, -1.26
Random effects		Variance	SD
	Intercept	5.65	2.38
Hypothesis 2b			
Fixed effects		Estimate	95% CI
	Intercept	-0.62	-1.10, -0.15
	Effort self-report	0.09	-0.00, 0.19
Random effects		Variance	SD
	Intercept	5.61	2.37

Discussion

Study 2 clarified that the unexpected finding that people are *more* likely to gamble at higher levels of effort investment in the context of our experimental paradigm is replicable. As such, at this point we were confident in the conclusion that any potential effort paradox may not be observed during a typical effort choice task (we elaborate on this finding and its implications in the general discussion). However, the findings from these two studies made us curious to what extent the continued devaluation of effort past its investment is robust to the framing of the study. Prospect theory (Kahneman & Tversky, 1979) states that people evaluate gains and losses differently, and this idea has been supported by recent work showing that people are more motivated to invest effort to *avoid losing rewards* compared to *gaining rewards* (Farinha & Maia, 2021; Massar et al., 2020). More generally, previous research indicates that people have a tendency to discount rewards more than losses, even when they are not tied to the investment of effort (Mitchell & Wilson, 2010). As such, if our finding were to replicate even when participants are investing effort to avoid losses, this would indicate that increased risk tolerance following effort investment happens robustly whether people are working to gain rewards or prevent losing them. On the other hand, a null result would be in line with previous work and suggest that effort has unique effects on risk aversion but only when it is tied to gaining rewards, which might indicate that this small effect is washed out by the larger effect of loss aversion.

Study 3

At this point, we were wondering to what extent our unexpected and replicated finding that people become *less* risk averse following effort investment depends on the framing of the study in terms of gaining rewards. As described above, research generally shows that people react stronger when faced with the possibility of losing rewards (vs gaining rewards). An open question is thus whether people also make more risky choices when they work hard to prevent the loss of rewards; or, in contrast, whether loss

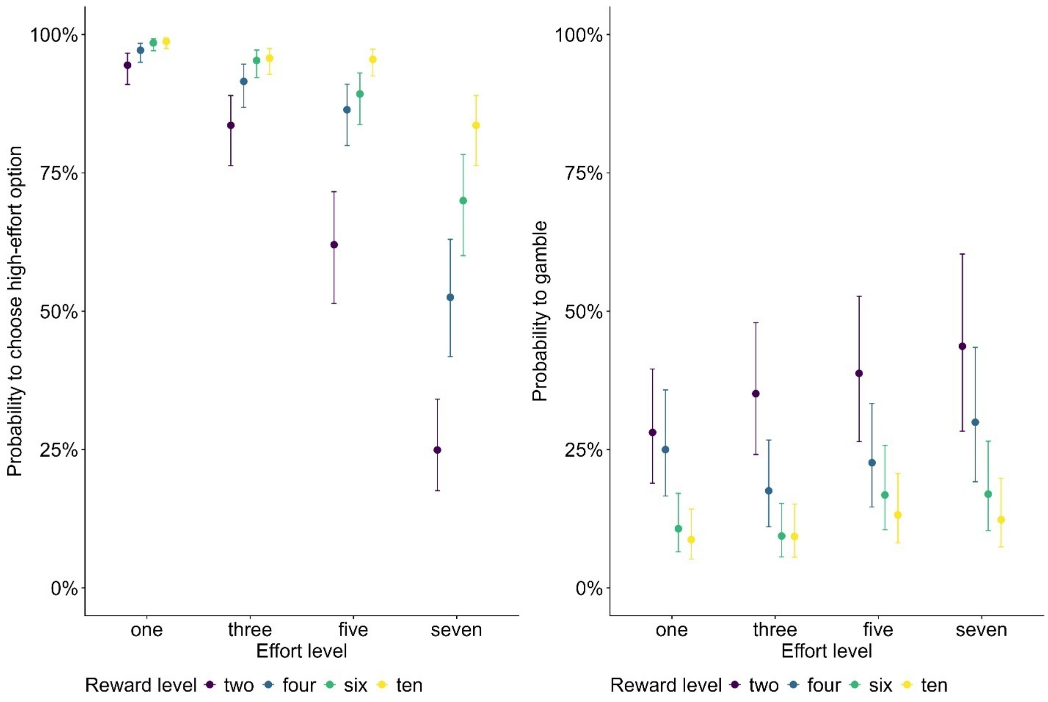

Figure 3. Predicted probabilities to choose for the high-effort option (left) and to choose to gamble with the rewards (right) as a function of effort and reward level in Study 2.

aversion 'drowns' out any effect of effort. Thus, Study 3 tested our predictions in the context of *avoiding losing* rewards.

Method

We once again preregistered our predictions and aimed for 150 participants. 150 participants (M_{age} = 21.32, 77 females) recruited via Prolific participated in exchange for £3.75 and a variable cash payment depending on the choices made in the experiment. The setup of the experiment was largely identical to Studies 1 and 2. The crucial difference was that rather than earning credits throughout the experiment, participants started out with 330 credits. They always lost a fixed amount for choosing the low-effort option (-10 credits) and lost a variable number of credits when choosing the high-effort option (-8 to -1 credits). Thus, in Study 3 we studied losses rather than rewards. Once again, participants could gamble with their losses, with a chance of reducing losses to zero, which came at a 50% risk of doubling the losses.

Results

Participants chose for the high-effort option in 84% of experimental blocks, and chose to gamble with the losses 43% of experimental blocks. They reported increasing subjective effort at increasing effort levels (M_{add1} = 26.6; M_{add3} = 45.6; M_{add5} = 55.0; M_{add7} = 70.7, p < .001). We first fitted a model predicting effort choice from effort level and reward level. This model had a prediction accuracy of 89%. We then fitted a model predicting gambling choice from effort level and reward level. This model had a prediction accuracy of 80%. Finally, we fitted a model predicting gambling choice from self-reported effort. This model had a prediction accuracy of 79%. Results are summarized in Table 3 and visualized in Figure 4.

Hypothesis 1

Once more, we found evidence for effort discounting: participants were *less* likely to choose the high-effort option the more effort it required (X^2 (3) = 656.27, p < .001), and were more *likely* to choose the high-effort option the fewer losses were associated with it (X^2 (3) = 364.35, p < .001). Compared to the lowest effort level (add 1), participants were estimated to be 27.11 times (95% CI = [19.89, 40.45]; Figure 4a) *less* likely to choose for the high-effort option at the highest effort level (add 7). Similarly, compared to the highest loss level (-8 credits), participants were estimated to be 13.60 times (95% CI = [9.87, 19.89]) *more* likely to choose for the high-effort option at the lowest loss level (-1 credit).

Hypothesis 2

In Study 3, gambling choice was neither predicted by effort level (X^2 (3) = 5.85, p = .108; Figure 4b), nor by subjective reports of effort (X^2 (1) = 1.91, p = .165).

Exploratory Analysis

Our preregistered analyses showed that (in a gain-framing context) people were more willing to gamble when they invested more effort. We were curious whether a similar effect could be observed in on a between-subject level, and whether any between-subject effect would differ in the gain and loss domain (similar to our within-subject analyses).

Table 3. Model results predicting the likelihood to choose the high-effort option (H1) and the likelihood to gamble (H2) in Study 3. The reference categories in both models are the lowest effort and reward level respectively. Model results need to be exponentiated to reflect odds ratios.

Hypothesis 1			
Fixed effects		Estimate	95% CI
	Intercept	2.83	2.46, 3.33
	Effort 3	-0.61	-1.00, -0.26
	Effort 5	-1.43	-1.83, -1.12
	Effort 7	-3.30	-3.70, -2.99
	Reward -6	1.05	0.81, 1.32
	Reward -4	1.91	1.62, 2.22
	Reward -1	2.61	2.29, 2.99
Random effects		Variance	SD
	Intercept	2.89	1.70
Hypothesis 2a			
Fixed effects		Estimate	95% CI
	Intercept	-0.30	-0.72, 0.17
	Effort 3	-0.24	-0.47, -0.03
	Effort 5	-0.18	-0.41, 0.04
	Effort 7	-0.24	-0.49, 0.01
	Reward -6	-0.38	-0.64, -0.14
	Reward -4	-0.30	-0.55, -0.05
	Reward -1	-0.00	-0.24, 0.24
Random effects		Variance	SD
	Intercept	5.19	2.28
Hypothesis 2b			
Fixed effects		Estimate	95% CI
	Intercept	-0.45	-0.87, -0.06
	Effort self-report	-0.06	-0.15, 0.02
Random effects		Variance	SD
	Intercept	5.16	2.27

For that reason, we explored whether participants who were more likely to choose the high-effort option also were more likely to gamble with the rewards they received, and whether this association differs depending on whether the study was framed in terms of gains or losses. This analysis indicated that participants who were more likely to choose high effort were also more likely to gamble (b = 0.29, 95% CI = [0.22, 0.36]), and that this effect was not moderated by the framing of the study (b = 0.04, 95% CI = [-0.12, 0.20]). Thus, results from this exploratory analysis (which are in need of replication) indicate that people who are more willing to invest effort also are more willing to gamble with the rewards tied to effort. This is an interesting avenue for future research, as it might indicate that a common trait underlies effort-based and risky decision making.

Discussion

Study 3 revealed that, contrary to a situation in which they may maximize their gains, people are not more likely to take a gamble to minimize losses following higher effort investment. This is in line with previous work showing differential effects of gains and losses on effort-related decision-making (Crawford et al., 2022; Farinha & Maia, 2021; Massar et al., 2020). We speculate that this may indicate that investing effort to gain rewards (compared to avoid losing them) results in higher levels of negative affect. This would explain the decreased susceptibility to effort in loss contexts found in earlier work as well as the pattern of results reported here. We elaborate on this idea in the general discussion.

General Discussion

In this project, we set out to test whether people paradoxically discount effort prospectively *and* value effort retrospectively within seconds. To explore this question, we asked participants first to repeatedly choose between performing a task requiring more effort for a higher reward and a task requiring less effort for a lower reward, as this allows us to observe the well-established phenomenon that people request higher rewards to perform a more effortful

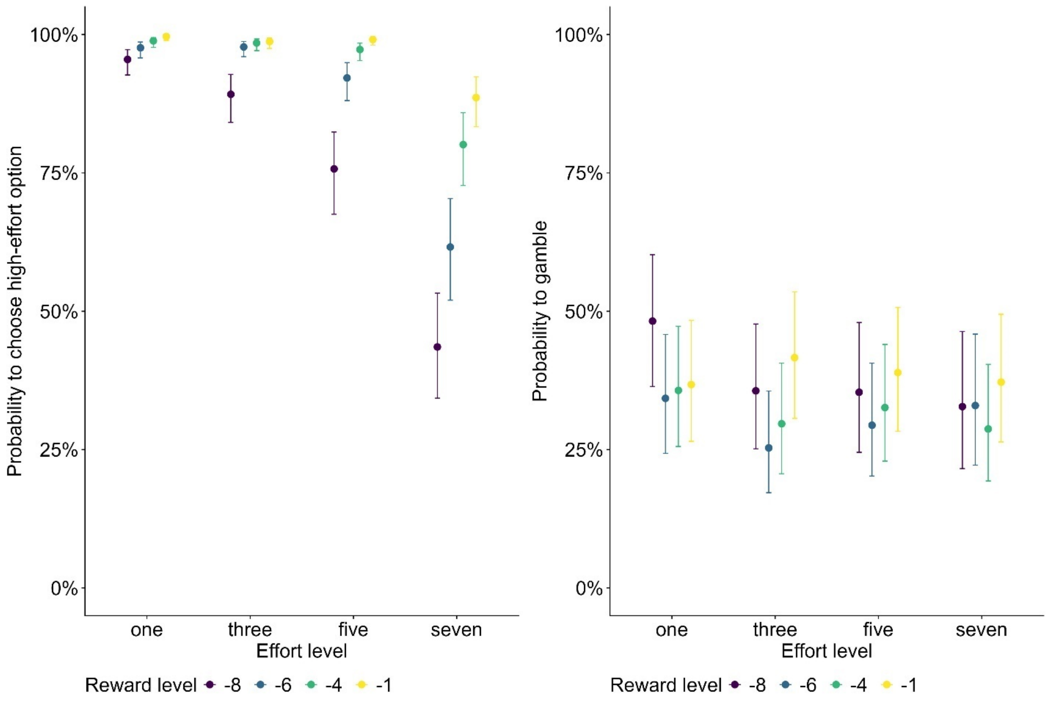

Figure 4. Predicted probabilities to choose for the high-effort option (left) and to choose to gamble with the rewards (right) as a function of effort and reward level in Study 3.

task. Then, we asked participants to choose whether or not to gamble with the rewards they received for the effort they just invested, as people tend to become more risk averse when they value something more (Christopoulos et al., 2009). Unsurprisingly, we found robust evidence for effort discounting (Apps et al., 2015; Westbrook et al., 2013); all else being equal, people demanded higher rewards to invest more effort. However, contrary to our preregistered prediction, in Studies 1 and 2 we observed that people were *more* likely to gamble with gains that were tied to a higher effort investment, which we interpret as being consistent with lower valuation of the rewards tied to effortful activity. An alternative interpretation of this finding may be that investing effort modulates risk perception directly rather than indirectly via subjective value (Oblak et al., 2018), for example via dopamine released in the midbrain (Coddington & Dudman, 2019; Voon et al., 2011; Westbrook & Braver, 2016). However, we consider this less likely due to previous null findings of effort on risk taking in a task that involved no gambling (Apps et al., 2015), showing that effort does not always promote risky decision-making.

Importantly, this finding did not replicate in Study 3 when participants were asked to gamble with losses rather than gains. Collectively, these results make it clear that we did not observe any potential effort paradox in the context of our experimental paradigm; people did not seem to gamble less immediately after having invested effort. In that sense, our results extend earlier work (Yi et al., 2020; Zentall, 2010) showing that effort is unlikely to add value subjectively in order to justify its expenditure, a prediction made by the justification of effort theory (Aronson, 1969).

Assuming that the gambling behavior in our study reflects a change in value, the results here provide evidence that we should not expect effort associated with a demanding task to be valued in the context of a typical effort choice task (Apps et al., 2015) in which participants are exposed to multiple levels of effortful demand (i.e., a within-subjects experimental treatment). This could have two related reasons. First, it is possible that participants in our experiments did not internalize the value of effort because they were aware prior to selecting how much effort to invest that higher effort would lead to higher reward and by how much. On the other hand, in the real world there is less certainty in this association; for example, a student is not guaranteed a higher grade prior to making the decision to study harder but tends to be rewarded with a higher grade. Perhaps this uncertainty is crucial for effort valuation (or learned industriousness; Eisenberger, 1992) to take place.

Second, it is possible that being exposed to both the high- and low-effort task makes any cognitive dissonance (such as discounting and then valuing effort) less likely to occur. Multiple studies have shown that similar biases display larger effects in studies making between-participant comparisons compared to within-participant comparisons (Johansson-Stenman & Svedsaeter, 2008; List & Gallet, 2001; Murphy et al., 2005). While these studies did not explore potential mechanisms of this phenomenon, one explanation is that in within-subjects designs (such as ours), participants necessarily become aware that more effort leads to higher reward deterministically. Importantly, previous research has shown that reward responses decrease over time if reward delivery is deterministic, but increase over time if reward delivery is probabilistic (Starkweather et al., 2017, 2018). In other words, it is possible that had we used a within-participant design with rewards delivered probabilistically, we might have seen a more robust effortinflation effect given the uncertainty of reward delivery leaving more room for (irrational) dissonance reduction processes. As such, future research should explore whether the effort paradox can be observed in a between-subjects design in which participants are less certain that higher effort will lead to higher reward prior to effort investment. For example, each participant could be randomly assigned to one of the four effort levels while higher effort probabilistically (but not with certainty) leads to higher rewards after the investment of effort.

An alternative interpretation of our findings may be that investing effort modulates risk perception directly rather than indirectly via subjective value (Oblak et al., 2018), for example via dopamine released in the midbrain (Coddington & Dudman, 2019; Voon et al., 2011; Westbrook & Braver, 2016). Another explanation, supported by cognitive neuroscience research, is that rewards earned after cognitive effort are encoded as less rewarding in the brain. For instance, Botvinick and colleagues (2009) demonstrated using fMRI that reward signals in the nucleus accumbens are discounted when earned following cognitive conflict. Similarly, Cavanagh and colleagues (2014) showed using EEG that rewards earned after conflict are encoded as less rewarding. If rewards earned after higher effort are indeed treated as less valuable, this would, according to Prospect Theory, lead to increased gambling propensity. This interpretation could also help explain why we only observed increased gambling in gain contexts - the reward devaluation effect might be less pronounced when people are working to avoid losses rather than gain rewards. In other words, as convincingly pointed out to us by our reviewers, our design does not allow us to conclude that effort investment led to a change in valuation which led to a change in gambling behavior in Study 2, as changes in gambling behavior might have been prompted by other unobserved processes. While we stated a priori that we would interpret changes in gambling behavior as reflecting changes in value, we now believe that further research is needed to establish convergent evidence before we can be confident in this conclusion. For example, as we know that people are more willing to exert effort for themselves compared to others(Depow et al., 2022; Lockwood et al., 2017), a future study could test whether participants are more willing to gamble when the effort was exerted on behalf of others. In summary, the only thing we can conclude with certainty is that effort does not lead to risk aversion.

One important direction for future research will be to manipulate the framing (gains vs. losses) in the context of a single study, as effects of such framing have been documented both on people's decision-making strategies and affective experience (Fischer et al., 2008; Nabi et al., 2020).Another interesting insight coming out of our experiments is that, surprisingly, we found and replicated a small effect that participants were somewhat more willing to engage in a risky gamble with rewards tied to higher effort investment, at least when the study was framed in terms of gains. One possible post-hoc explanation for this finding is that participants' momentary affect fluctuates with the amount of effort they just invested. We know that effort feels aversive (Bijleveld, 2018; Dreisbach & Fischer, 2015; Inzlicht et al., 2015), and some research indicates that people become less risk averse following a temporarily induced state of sadness (Raghunathan & Pham, 1999). Our findings could indicate that the aversive feeling that accompanies effort similarly increases risky decision-making. This would be in line with the mood maintenance hypothesis (Isen et al., 1988; Isen & Patrick, 1983), which predicts that people engage in risky behaviors when experiencing negative affect in the hopes of improving their mood. The fact that we did not find this effect when we framed the study in terms of losses might highlight differential affective changes following effort investment for gains and to prevent losses respectively. Although speculative, this would explain why people consistently become less susceptible to aversive effort effects when avoiding losses (Crawford et al., 2022; Farinha & Maia, 2021; Massar et al., 2020). If the positive finding from Studies 1 and 2 replicates in future research across various study designs, this would imply that by manipulating effort we could nudge people to become more or less risk averse in contexts such as gambling, financial decision-making, and substance use. For example, future research could measure negative affect following effort investment to see if it mediates the association between effort and risk taking.(Fischer et al., 2008; Nabi et al., 2020)

Related to the differential effects of effort on gambling choices in the context of gains and losses, it is important to highlight that we recruited three samples of young adults. Previous work has shown that a motivational shift takes place as people mature from a focus on maximizing gains in young adulthood to avoidance of losses in later adulthood (Ebner et al., 2006; Gong & Freund, 2020; Mustafic & Freund, 2012). Similarly, one study found that the effect of gain versus loss framing on effort investment was moderated by age, with younger adults being more motivated to exert effort to accrue gains and older adults being more motivated to avoid losses (Byrne & Anaraky, 2019). To that end, we believe future work should explore to what extent our results replicate in older adults.

In sum, across three preregistered experiments we showed clearly that we should not expect effort to lead to increased risk aversion in within-participant experimental designs in which rewards tied to various levels of effortful activity are announced prior to the decision to invest effort, and we outline how future studies could extend these findings. Unintentionally, we also showed for the first time that investing effort might make people less risk averse, potentially via the aversive feeling that accompanies effort. Given that risky decision-making can be problematic across a variety of contexts, it may well be useful to study the role effort might play in this process.

Author Contributions

J. Dora and M. Inzlicht conceived and designed the study idea. J. Dora programmed the experiments, collected and analyzed the data. J. Dora and M. Inzlicht wrote, reviewed, edited, and approved the manuscript.

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Competing Interests

The authors have no competing interests to disclose.

Data Accessibility Statement

All de-identified participant data and analysis scripts are available on the Open Science Framework: https://osf.io/cqxfk/

Ethics Statement

The authors have complied with the APA ethical principles regarding research with human participants in the conduct of the research presented in this manuscript.

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Supplementary Materials

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