Make or break: The influence of expected challenges and rewards on the motivation and experience associated with cognitive effort exertion

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Abstract

Challenging goals can induce harder work but also greater stress, in turn potentially undermining goal achievement. We sought to examine how mental effort and subjective experiences thereof interact as a function of challenge level and the size of the incentives at stake. Participants performed a task that rewarded individual units of effort investment (correctly performed Stroop trials) but only if they met a threshold number of correct trials within a fixed time interval (challenge level). We varied this challenge level (Study 1, N = 40), and the rewards at stake (Study 2, N = 79), and measured variability in task performance and self-reported affect across task intervals. Greater challenge and higher rewards facilitated greater effort investment but also induced greater stress, while higher rewards (but less challenge) simultaneously induced greater positive affect. Current findings further our understanding of task demands and incentives on mental effort exertion and wellbeing.

Keywords: goal pursuit, expected challenge, stress, affect, monetary incentive

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Goal attainment in everyday life requires exerting cognitive control. We exert control to fuel the necessary performance to reach the goal. However, control is effortful and how much control a person is willing to invest in reaching a goal depends on how motivated they are. Recent work has characterized the motivational factors that determine effort investment in a control-demanding task (e.g., Stroop-like tasks that require an individual to respond to a target feature while ignoring a distractor) (Botvinick & Braver, 2015).This work has shown that people adjust their level of control allocation based on performance-outcome contingencies (e.g., monetary rewards and penalties) and the expected challenge level of the task (e.g., target-distractor incongruency) in order to maximize performance toward a given goal (e.g., Bugg et al., 2011; Krebs et al., 2010; Leng et al., 2021). However, how control allocation adjusts to the level of challenge presented by the goal itself remains unclear.

A large body of work in the field of organizational behavior shows that setting a challenging but attainable goal leads to better performance, relative to having no goal, a goal that is too challenging (e.g., a hard-to-meet performance target), or a goal that is not challenging enough (e.g., an easy-to-meet performance target) (Locke, 1968). Although a substantial body of work has gone into establishing and testing the goal setting theory, there are important elements of this theoretical framework that remain underexplored, in part due to limitations of past experiments. For instance, research on goal-setting often examines goal commitment over long timescales and almost always based on self-report while ignoring behavioral indicators, such as how much and how long effort was exerted (Klein et al., 2013). It is therefore largely unknown how variability in challenge levels translate into within-participant changes in trial-by-trial

performance on a control-demanding task. Recent approaches to studying interactions between motivation and cognitive control offer this additional level of granularity (e.g., by revealing how accuracy and response time vary as a function of incentive level; see Botvinick & Braver, 2015), but have yet to examine this critical component of motivation's role in shaping control, nor how it interacts with the incentives for performance.

Several lines of work offer clues as to how expected challenges and incentives will interact to determine control allocation. Goal-setting theories, as well as an analogous line of research under the framework of Motivational Intensity Theory (Richter et al., 2016), predict that increasing levels of expected incentives and expected challenge should promote greater investment of mental effort, up to the point where it is no longer efficacious for improving performance (i.e., when the goal is increasingly impossible to meet), after which these theories predict that control will be divested (Shenhav et al., 2021; Silvestrini et al., 2023). This prediction has yet to be tested directly in the context of traditional cognitive control tasks. It is therefore also unclear to what extent increasingly challenging goals lead people to adjust the *type* of control they invest (e.g., their focus on speed versus accuracy) and how they dynamically adjust these control levels as they approach and after they have met their goal.

Separate from their role in motivating effort, it is also known that challenging tasks can induce negative affective experiences such as feelings of stress, which could in turn serve to undermine performance (Byron et al., 2016; Espedido & Searle, 2018). The factors that determine such feelings of acute stress are poorly understood, in part because these experiences are either not measured (as in the majority of research on motivation-control interactions) or are measured at a wide temporal scale (e.g., at the level of an experiment; Harvey & Victoravich,

2009; Henkel & Hinsz, 2004). It thus remains to be determined to what extent challenge level[1] (and ensuing performance, including whether one succeeds or fails at meeting their goal) influence task-related experiences of both positive and negative affect. A particularly intriguing and as-yet-unaddressed question relates to how monetary incentives and challenge level might interact to determine momentary affective experiences of a task. Higher monetary reward should amplify one's achievement if a goal is attained, leading to greater positive affect, but how these incentive levels affect stress is less clear. Past work suggests two intuitive but diametrically opposed hypotheses: increasing reward incentives could increase or decrease acute stress levels while progressing towards goal completion.

Here, we sought to build on past work to examine how performance and affect vary, and potentially interact, within a given person based on the level of challenge and stakes they are facing in performing a cognitively demanding task. Across two studies, we examine the influence of expected challenge level on (1) how much effort a person exerts and (2) the subjective affective experiences they feel while doing so, focusing on acute stress. We devised a timed, incentivized cognitive control task, wherein participants had to meet a specific goal threshold (number of correct trials) to receive their accumulated rewards. Throughout the experiment, we varied this goal threshold (i.e., challenge level) and measured how this influenced performance within and across time intervals, and how it influenced self-reported affective experiences. In Experiment 2, we additionally varied the amount of reward received for

[1] We use the phrase "challenge level" to distinguish from "task difficulty" as noted in Locke et al (1981). The authors had coined the term difficulty to refer to the difficulty of the task itself (e.g., writing a novel is much harder than writing a birthday card). On the other hand, challenge level usually refers to attaining a specific standard of proficiency within a time limit (e.g., completing 20 versus 5 simple arithmetic questions within 10 minutes has distinct challenge level), which is what we manipulated in our tasks.

each correct response, to test how levels of expected reward interacts with challenge level in impacting effort and affect.

Consistent with past research on goal setting, we observed increased motivation with more challenging goals, such that participants would put in more effort and persist longer with their effort to achieve a higher goal. We also found better performance in high reward conditions. At the same time, we found that participants felt more stressed with both higher challenge level and higher monetary stakes, but that these factors diverged in their influences on positive affect, with greater challenge producing less positive affect and greater reward producing more. We further exploited our unique experimental approach to examine how goal proximity influences task performance, and how task performance interacts with challenge level to influence affective experiences.

Experiment 1: The effect of challenge level on performance and affective experiences

Methods

Participants

We recruited 40 participants online through Prolific (https://www.prolific.co/). All participants indicated that they had normal or corrected-to-normal vision and color vision prior to completing the study. Consent was given in compliance with Brown University's Institutional Review Board. Participants were compensated for their time and received an additional monetary bonus based on their performance of the task. Two participants were excluded from our analyses because their affective ratings were uniform throughout the experiment, resulting in a final sample of 38 participants (Age: 18-51 (M = 28.5, SD = 8.19); Female = 17).

Task

To examine the effects of challenge level on cognitive effort exertion and the associated affective experiences, we developed a self-paced incentivized cognitive control task based on one previously used by Leng and colleagues (2021) (Figure 1A). In our task, participants were given fixed time intervals of 8 seconds to perform the classic color Stroop Task, which was designed to induce and measure cognitive effort (MacLeod, 1991). In the color-word Stroop task, participants had to name the ink color of a color word. There were four possible ink colors (red, yellow, green and blue) across four possible color words ('RED', 'YELLOW', 'GREEN', 'BLUE'). Participants were instructed to press the key corresponding to the ink color of each stimulus. The ink color could be congruent (e.g., **BLUE**) or incongruent (e.g., **BLUE**) with the meaning of the word. Responding to incongruent stimuli has been shown to require an override of their more automatic tendency to respond based on the word meaning. The overall proportion of congruent (versus incongruent) trials was 50%. Due to the self-paced nature of design the proportion of congruent trials could vary slightly across intervals, and was therefore included as a covariate in interval-level analyses. Participants were instructed to complete as many Stroop trials as they wanted during each time interval, and were told that each correct response would result in reward (in the form of "gems"), which could proportionately translate to monetary bonus rewards at the end of the task (5 gems = $0.01).

For each interval, there was a specific minimum number of correct responses that participants would have to complete in order to receive their rewards (the *goal threshold*). If the goal threshold was reached, the interval would yield a number of gems equal to the number of correct responses during that interval. If the goal threshold was not reached, the interval would yield 0 gems, regardless of the number of correct responses. We manipulated challenge level by varying the goal threshold across intervals. "Easy" intervals required only 5 correct responses to

receive the bonus reward, whereas “Hard” required 8 correct responses to meet this threshold. These threshold values were selected based on pilot studies, which suggested that the higher goal threshold would generally be achievable but require more effort to meet than the lower goal threshold.

The challenge level for an upcoming interval was cued prior to the start of each interval (Figure 1B). A tracker at the bottom of the screen provided participants with real-time feedback regarding the cumulative number of correct trials within that interval. The tracker also served as a reminder of the goal threshold, indicating where their cumulative reward stood relative to the number of correct responses required. Participants also received feedback at the end of each interval regarding whether they had met their goal and how much reward (i.e., the number of gems) they earned for that interval.

We also measured affective experiences throughout the experiment. After each interval, we prompted participants to rate their affect during the preceding interval. Participants were asked to either rate their stress level (“How stressed did you feel during the previous turn?”) or their level of positive affect (“How good did you feel during the previous turn?”) on a scale of 0 to 10. Participants were only given one of these questions after each interval, with an equal number of each question asked and the ordering of the questions pseudorandomized within each block of 8 intervals.

The experiment was organized in large blocks of intervals of the same challenge level for within-subject comparisons of acute stress induced from said challenge. Challenge levels of blocks were varied pseudorandomly and in equal proportion across the experimental session. Each participant completed 4 blocks of 8 intervals per block and were instructed that the bonus

reward from 2 intervals per block will be selected at the end of the task for bonus payment. This encouraged participants to treat each interval and block independently in terms of their level of effort investment, in part as a mitigant against fatigue effects, though all analyses also control for such order effects. The order of blocks was randomized across participants. Participants were also given ample practice with the Stroop task (score at least 5 correct trials in a row or a maximum of 60 trials) and task structure (4 intervals with the general interval structure and 2 intervals of practice with each set of cues) prior to the onset of the actual task. To ensure understanding of task instructions, participants were required to correctly complete short tests of task comprehension before continuing to the main experiment.

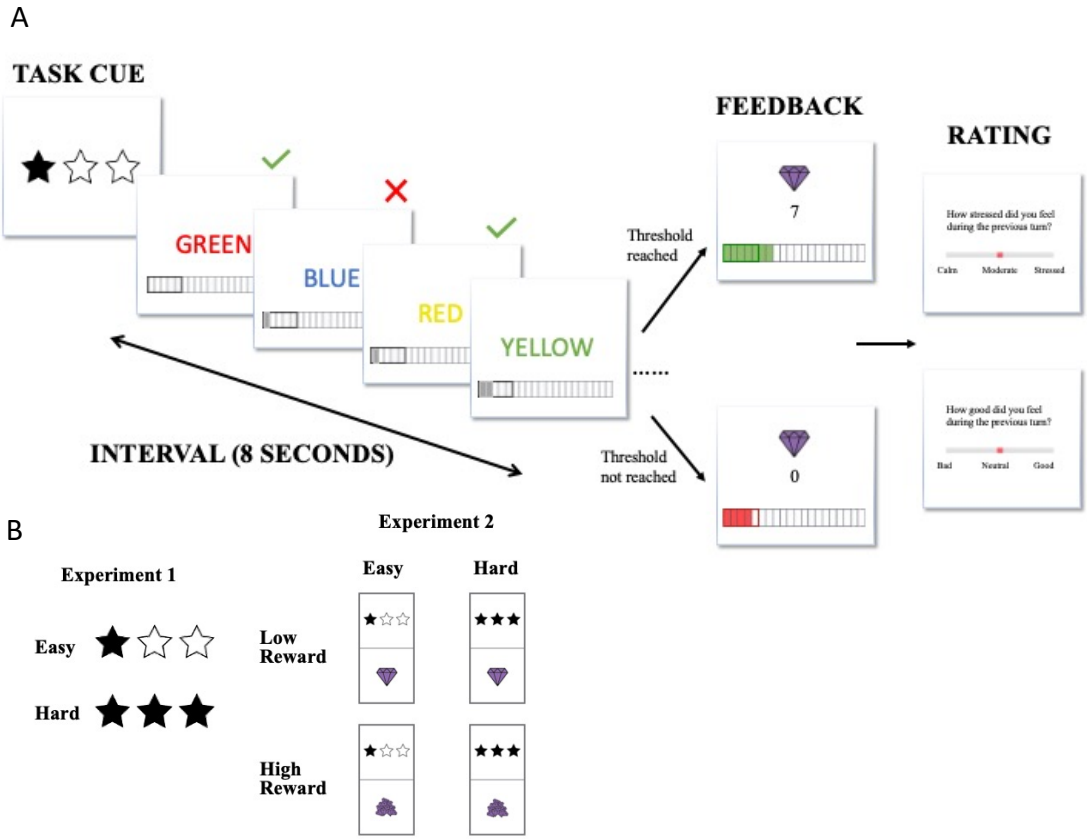

Figure 1. *Task Schematics.* (A) Each experiment contained 4 blocks of Stroop trials, with each block split into 8 smaller time intervals that lasted 8 seconds each. At the start of each interval, a cue is presented briefly to indicate challenge level (and reward level in Experiment 2) for the given interval. Participants

can complete as many Stroop trials as they want before the time runs out. A tracker is displayed at the bottom of the screen and reflected the goal threshold and cumulative correct responses as real-time feedback in addition to the summary feedback at the end of each interval. If participants succeed in completing or exceeding the goal, they will have a chance to receive the reward corresponding to the number of trials they had completed. If participants failed to reach the goal, they will not receive any reward for that interval regardless of many correct responses they had made. After each interval, participants rated either their level of stress or positive affect during the preceding interval on a scale of 0 to 10. (B) Task cues in each experiment.

Measures and Analyses

As our main performance metrics, we measured reaction time and accuracy of Stroop trials. We also collected self-reported ratings of affect, as described above. With the current paradigm, we can analyze performance at the level of given time-intervals and at the level of individual trials of Stroop responses (Leng et al., 2021). We analyzed interval-level performance (correct trials per second) and self-report affective ratings by fitting linear mixed models (lme4 package in R; Bates et al., 2015) to estimate these parameters as functions of contrast-coded challenge level (Easy = -1, Hard = 1). The models controlled for the proportion of congruent vs. incongruent stimuli in a given interval, as well as the interval order within a block (1-8) and across the entire session (1-32). We examined effects of congruency and report the results in supplements (Supplement Table 1 & Supplement Table 2). All continuous variables (e.g., interval order) were z-scored. All of our mixed models used maximally specified random effects (Barr et al., 2013).

We also analyzed accurate reaction time and accuracy at the trial level by fitting linear (RT) or logistic (accuracy) mixed models to estimate these parameters as functions of challenge level and whether the trial had been completed before or after the goal was reached. These models controlled for stimulus congruency, interval number, and trial number over the course of the session.

Results

Effects of expected reward and challenge on overall performance

Overall, participants successfully met their minimum interval goals on 95.1% of easy intervals (goal = 5 correct trials) but only 74.8% of hard intervals (goal = 8 correct trials; χ^2 (1, N = 38) = 13.54, p < 0.001, Table 1). On average, participants completed 8.62 correct trials per easy interval and 8.83 correct trials per hard interval. At the same time, we found that participants reached the higher goal threshold (i.e., 8 correct trials per interval) on 69.5% of easy intervals, which is significantly lower than that in hard intervals (χ^2 (1, 38) = 8.12, p = 0.004).

When participants faced hard intervals, they completed more correct trials per second (i.e., higher response rate) in a given interval compared with easy interval (*F*(1, 36.70) = 38.23, p < 0.001; Figure 2A, Table 2). This was reflected in faster trial-wise correct responses (i.e., speed, *F*(1, 32.7) = 35.96, p < 0.001; Figure 2B) and better trial accuracy (χ^2 (1, N = 38) = 10.97, p < 0.001; Figure 2C) (Supplement Table 3). In these models, we controlled for whether the participants had reached the interval goal, where we saw (as would be expected) higher response rate in intervals where the goal had been completed *F*(1, 36.7) = 421.89, p < 0.001). We again find this effect reflected in both faster speed *F*(1, 26.7) = 82.93 , p < 0.001) and better accuracy in intervals where the goal was reached versus not reached (χ^2 (1, N = 38) = 221.26, p < 0.001).

Table 1. Mixed Model Results for Interval Goal Attainment and Higher Goal Attainment (Experiment 1)

Predictors	Interval Goal Reached			High Goal Reached		
	Log Odds Ratios	*SE*	*p-value*	*Log Odds Ratios*	*SE*	*p-value*
Hard - Easy	-1.15	0.10	**< 0.001*** **	0.33	0.16	**0.004*** **
Average Congruency	-0.21	0.10	0.080	-0.15	0.08	0.089
Scaled Interval Session Num[1]	0.07	0.14	0.601	-0.03	0.09	0.742
Scaled Interval Block Num[2]	-0.06	0.11	0.627	-0.12	0.08	0.155

1. Scaled interval number across the experiment session
2. Scaled interval number within each block

Table 2. Mixed Model Results for Correct Responses per Second (Experiment 1)

Predictors	Response Rate		
	Estimates	*SE*	*p-value*
Hard - Easy	0.05	0.01	**< 0.001*** **
Interval Goal Completion[1]	0.42	0.02	**< 0.001*** **
Average Congruency	0.00	0.01	0.614
Scaled Interval Session Num	-0.00	0.01	0.336
Scaled Interval Block Num	0.01	0.00	0.508

1. Whether participants had reached the goal for that interval (1: reached, 0: not reached)

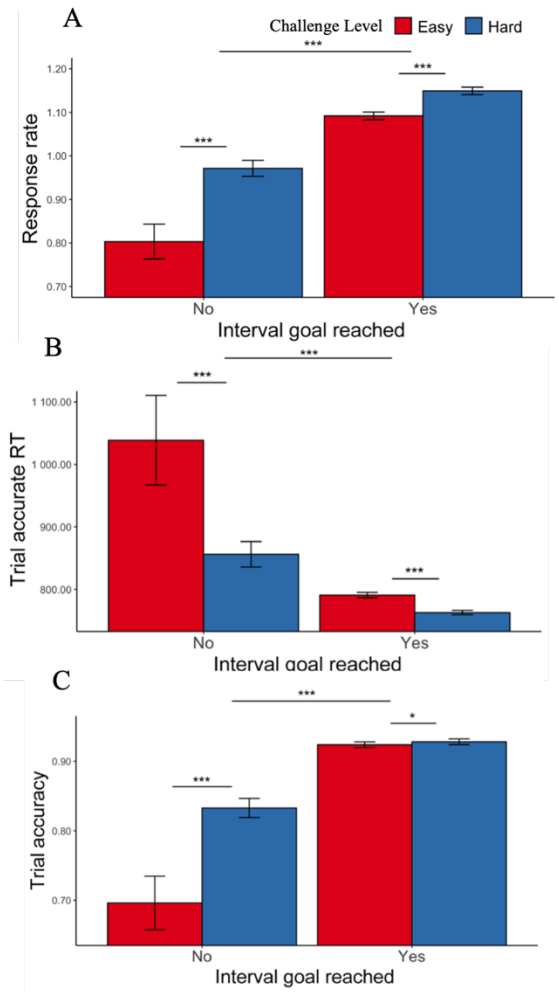

Figure 2. *Effects of challenge level and goal completion on performance (Experiment 1*). (A) When participants faced hard intervals, they completed more correct trials per second. When they had reached the interval goal, we intuitively found higher response rate compared with intervals where the goal was not reached. This is reflected in both (B) faster trial-wise reaction time for correct trials and (C) higher trial accuracy. Error bars reflect standard errors. ***: $p < 0.001$; *: $p < 0.05$

Effects of goal completion and proximity on performance

The findings above describe aggregate performance as challenge level varied, but our experimental design allowed us to examine performance on a more granular level: to see how it

varied on a trial-by-trial level as participants approached the goal, and after they surpassed it. In our task, prior to reaching the minimum number of trials for a given interval, participants were incentivized to reach the goal before the deadline (otherwise risking foregoing any reward for that interval). After meeting this minimum goal, though, they were still rewarded for each correct response and were therefore incentivized to keep completing as many trials as they could, such that participants could obtain the same amount of reward across both easy and hard intervals. We were therefore interested in the extent to which performance would maintain or differ before and after reaching a goal (focusing only on intervals in which that minimum goal was met).

Consistent with the findings above, we found a main effect of challenge level on performance, such that participants were more likely to respond accurately, and faster to do so, during more challenging intervals (Figure 3, Table 3). We further found that performance differed before versus after meeting the goal, with trials completed after meeting an interval's threshold being faster ($F(1, 27.5) = 15.18$, $p < 0.001$; Figure 3A) without any change in accuracy (χ^2 (1, N = 38) = 0.17, p = 0.678; Figure 3B) (Table 3). Goal completion and challenge level also interacted to determine accuracy (χ^2 (1, N = 38) = 4.37, p = 0.036), such that after reaching their minimum goal, participants exhibited a drop in accuracy for hard intervals but an increase in accuracy for easy intervals (Figure 3B, Table 3). A trending interaction was observed for response time ($F(1, 7271.4) = 3.43$, $p = 0.064$), such that participants sped up for easy but not hard intervals after reaching their goal (Figure 3A). These analyses controlled for trial number within an interval, in part to account for differences in the timepoint at which thresholds were met during easy versus hard intervals.

Table 3. Mixed Model Results for Reaction Time and Accuracy (Experiment 1, goal-reached intervals only)

Predictors	Reaction Time (for accurate trials)			Accuracy		
	Estimates	*SE*	*p-value*	*Log Odds Ratios*	*SE*	*p-value*
Hard - Easy	-34.88	6.11	**< 0.001*** **	0.15	0.08	**0.013***
Trial Goal Completion[1]	-40.21	10.32	**< 0.001*** **	-0.01	0.10	0.911
Scaled Trial Session Num[2]	-11.96	14.33	**<.001*** **	-0.53	0.19	**0.005** **
Scaled Interval Session Num	14.39	14.12	0.404	0.45	0.19	**0.017***
Scaled Interval Block Num	-1.38	2.45	0.572	0.04	0.04	0.340
Challenge X Trial Goal Completion	10.41	5.62	*0.064*	-0.19	0.09	**0.036***

1. Whether the trial was completed before or after reaching the goal (0: before; 1: after)
2. Scaled trial number across the experiment session

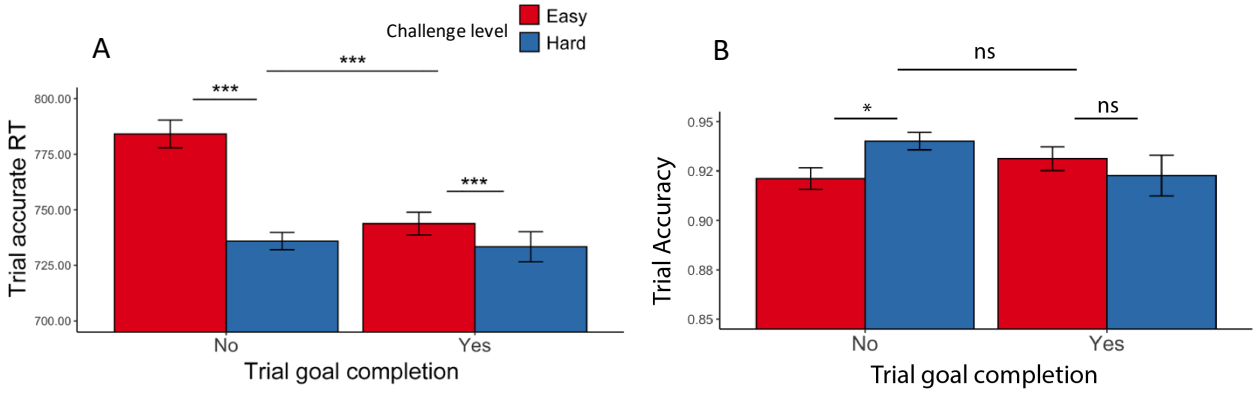

Figure 3. *Goal completion effects (goal reached intervals only, Experiment 1).* (A) Participants were overall faster after they had reached the interval goal. (B) Though there were no significant changes in accuracy before and after completing the goal, we found a significant interaction between goal reached and challenge level. Error bars reflect standard errors. ***: $p < 0.001$; *: $p < 0.05$

We also examined whether goal proximity, namely how far a certain trial was from the goal threshold, had an impact on performance. We similarly selected for intervals where the minimum goal had been completed, and further controlled for an interval's challenge level. We found that participants initially sped up after starting the interval for approximately 2 trials, then gradually slowed as they neared and surpassed the goal (Figure 4). To avoid conflating the effect of goal proximity with distance from this initial speeding effect, we excluded those first two

trials in each interval. We also excluded the last trial in each interval to avoid potential confounds related to unstable performance at the end of each time interval. After excluding these trials, we found that participants slowed down as they neared the goal ($F(1, 23.5) = 34.32$, $p < 0.001$), while maintaining similar levels of accuracy (χ^2 (1, N = 38) = 0.07, p = 0.850, Table 4, Figure 4). We also found an interaction between goal proximity and challenge level on accuracy, such that participants became less accurate when nearing a challenging goal, but not when nearing the easier goal (χ^2 (1, N = 38) = 7.20, p = 0.007). While our analyses control for order effects across the session (e.g., interval and block number), we cannot rule out the possibility that this interaction reflects the fact that goal-proximal trials on challenging intervals are also later in the interval, and potentially reflect within-interval order effects such as fatigue (note that the same concern does not hold for the main effects reported above).

Together, these results show that more challenging goals motivate better overall performance, seen in both faster and more accurate responses. Within a given interval, we see that these challenge-related performance improvements are reflected in trials both before and after goal completion.

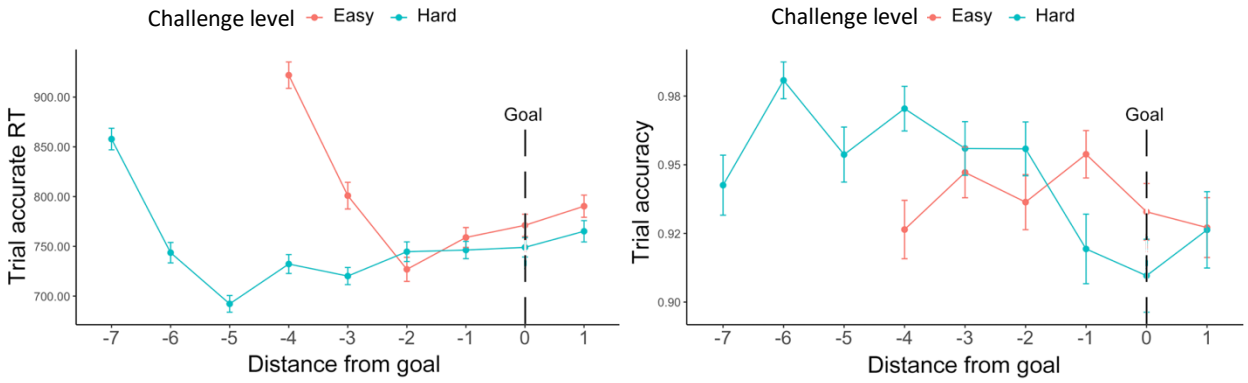

Figure 4. *Goal proximity effects (Experiment 1).* Overall, participants were slowest early in the interval (during the first two trials) and then gradually slowed again as they got closer to reaching their goal. Their accuracy did not vary with goal proximity. Error bars reflect standard errors.

Table 4. Mixed Model Results for Goal Proximity Effect for Reaction Time and Accuracy (Experiment 1)

Predictors	Response Time (for accurate trials)			Accuracy		
	Estimates	*SE*	*p-value*	*Log Odds Ratios*	*SE*	*p-value*
Goal Distance[1]	-27.88	4.76	**< 0.001*** **	-0.01	0.07	0.850
Hard – Easy	-14.87	4.62	**0.001*** **	0.12	0.08	0.102
Scaled Trial Session Num	-3.65	15.47	0.813	-0.49	0.13	**0.019***
Scaled Interval Session Num	-2.47	15.42	0.873	0.37	0.31	0.089
Scaled Interval Block Num	-4.40	2.62	0.093	0.08	0.06	0.118
Goal Distance X Challenge	3.47	3.28	0.291	0.17	0.08	**0.007** **

1. The distance of a trial from the goal

Effects of challenge level and performance on affective experiences

We next examined what elements of the task led to changes in affective states. As expected, we found that one's success or failure at reaching their goal for a given threshold significantly influenced affect (Figure 5, Table 5): participants reported feeling less positive ($F(1, 19.6) = 26.73$, $p < 0.001$) and more stressed ($F(1, 54.1) = 29.18$, $p < 0.001$) during intervals where they failed to reach a goal.

Focusing on intervals where participants had successfully met their goal, we found main effects of challenge level on affective experiences, such that participants felt worse ($F(1, 38.5) = 5.19$, $p = 0.023$) and more stressed ($F(1, 35.3) = 14.44$, $p < 0.001$) while performing hard intervals compared with easy intervals (Table 6). We found that when participants completed more correct responses per second, they reported less stress ($F(1, 39.0) = 24.47$, $p < 0.001$) and greater positive affect ($F(1, 38.8) = 36.72$, $p < 0.001$; Table 7, Figure 6A-B). This was reflected in analogous associations with faster average reaction time and higher average accuracy (Table 8, Table 9, Figure 6C-F). Together, these results suggest that the challenge-induced affective experience (i.e., higher stress, less positive affect) was reduced as participants performed better.

We also observed a significant interaction between challenge level and response rate in predicting positive affect ($F(1, 149.1) = 9.69$, $p = 0.002$), such that the increase in positive affect due to higher response rate was enhanced in more challenging relative to less challenging intervals. Similar interactions were observed between average accuracy and challenge level in predicting stress ratings ($F(1, 395.3) = 6.62$, $p = 0.010$) and positive affect ($F(1, 38) = 4.21$, $p = 0.040$), such that performing with higher accuracy reduced the challenge-induced affective experience (i.e., higher stress, less positive affect). This interaction between performance and challenge level was only observed for accuracy and not also response time (*p*s > .470).

Taken together, these results indicate that challenge level and performance both impact affective experiences during the task, such that easier intervals and better performance were associated with more positive and less negative affect. Notably, better performance, particularly higher accuracy, appeared to mitigate the negative affect that was brought about by challenge level (provided the participant had met the goal for that interval).

Table 5. Mixed Model Results for Affective Ratings Based on Challenge Level and Goal Completion (Experiment 1)

Predictors	Stress			Positive Affect		
	Estimates	*SE*	*p-value*	*Estimates*	*SE*	*p-value*
Hard - Easy	-0.15	0.27	0.580	0.01	0.30	0.983
Interval Goal Completion	-1.71	0.32	**< 0.001*** **	2.33	0.45	**< 0.001*** **
Average Congruency	0.12	0.08	0.107	0.04	0.09	0.678
Scaled Interval Session Num	0.02	0.07	0.820	-0.28	0.09	**0.001*** **
Scaled Interval Block Num	0.02	0.07	0.740	-0.01	0.08	0.897
Challenge X Interval Goal Completion	0.59	0.27	**0.030***	-0.21	0.31	0.495

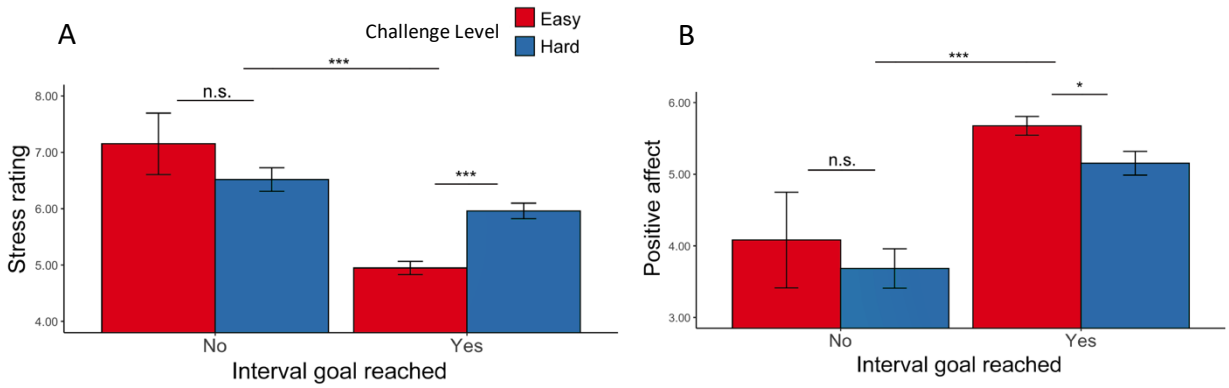

Figure 5. *Affective Ratings based on goal completion and challenge level (Experiment 1).* (A) Stress Ratings: Participants reported feeling more stress when they failed to reach the goal. In intervals where the goal was reached, they also reported feeling more stressed in hard intervals. (B) Positive Affect: Along the same line, participants reported to have felt worse when they failed to complete the goal and after completing the goal in hard intervals. Error bars reflect standard errors. ***: $p < 0.001$; *: $p < 0.05$

Table 6. Mixed Model Results for Affective Ratings Based on Challenge Level (Goal Completed Intervals Only, Experiment 1)

Predictors	Stress			Positive Affect		
	Estimates	*SE*	*p-value*	*Estimates*	*SE*	*p-value*
Hard - Easy	0.46	0.12	**< 0.001*** **	-0.23	0.10	**0.023***
Average Congruency	0.12	0.09	0.159	0.01	0.10	0.947
Scaled Interval Session Num	-0.02	0.08	0.782	-0.35	0.09	**< 0.001*** **
Scaled Interval Block Num	0.03	0.08	0.746	0.08	0.09	0.356

Table 7. Mixed Model Results for Affective Ratings Based on Response Rate (Goal Completed Intervals Only, Experiment 1)

Predictors	Stress			Positive Affect		
	Estimates	*SE*	*p-value*	*Estimates*	*SE*	*p-value*
Response Rate	-1.12	0.23	**< 0.001*** **	1.56	0.26	**< 0.001*** **
Hard - Easy	0.56	0.11	**< 0.001*** **	-0.46	0.09	**< 0.001*** **
Average Congruency	0.13	0.07	0.083	-0.06	0.07	0.390
Scaled Interval Session Num	-0.02	0.07	0.780	-0.32	0.07	**< 0.001*** **
Scaled Interval Block Num	0.05	0.07	0.500	-0.03	0.07	0.697
Response Rate X Challenge	-0.15	0.11	0.172	0.29	0.09	**0.002** **

Table 8. Mixed Model Results for Affective Ratings Based on Average Reaction Time (Goal Completed Intervals Only, Experiment 1)

Predictors	Stress			Positive Affect		
	Estimates	*SE*	*p-value*	*Estimates*	*SE*	*p-value*
Mean Accurate RT	0.61	0.22	**0.005****	-0.71	0.22	**0.001*****
Hard - Easy	0.50	0.14	**< 0.001*****	-0.33	0.12	**0.004****
Average Congruency	0.15	0.08	0.074	-0.03	0.10	0.721
Scaled Interval Session Num	-0.04	0.08	0.646	-0.35	0.09	**< 0.001*****
Scaled Interval Block Num	0.01	0.08	0.854	0.06	0.09	0.472
Mean Accurate RT X Challenge	0.02	0.16	0.911	-0.11	0.15	0.473

Table 9. Mixed Model Results for Affective Ratings Based on Average Accuracy (Goal Completed Intervals Only, Experiment 1)

Predictors	Stress			Positive Affect		
	Estimates	*SE*	*p-value*	*Estimates*	*SE*	*p-value*
Mean Accuracy	-1.13	0.17	**< 0.001*****	1.51	0.23	**< 0.001*****
Hard - Easy	0.53	0.10	**< 0.001*****	-0.36	0.09	**< 0.001*****
Average Congruency	0.07	0.08	0.387	0.00	0.08	0.988
Scaled Interval Session Num	-0.02	0.07	0.740	-0.32	0.08	**< 0.001*****
Scaled Interval Block Num	0.04	0.08	0.561	0.02	0.07	0.76
Mean Accuracy X Challenge	-0.33	0.13	**0.010****	0.25	0.12	**0.040***

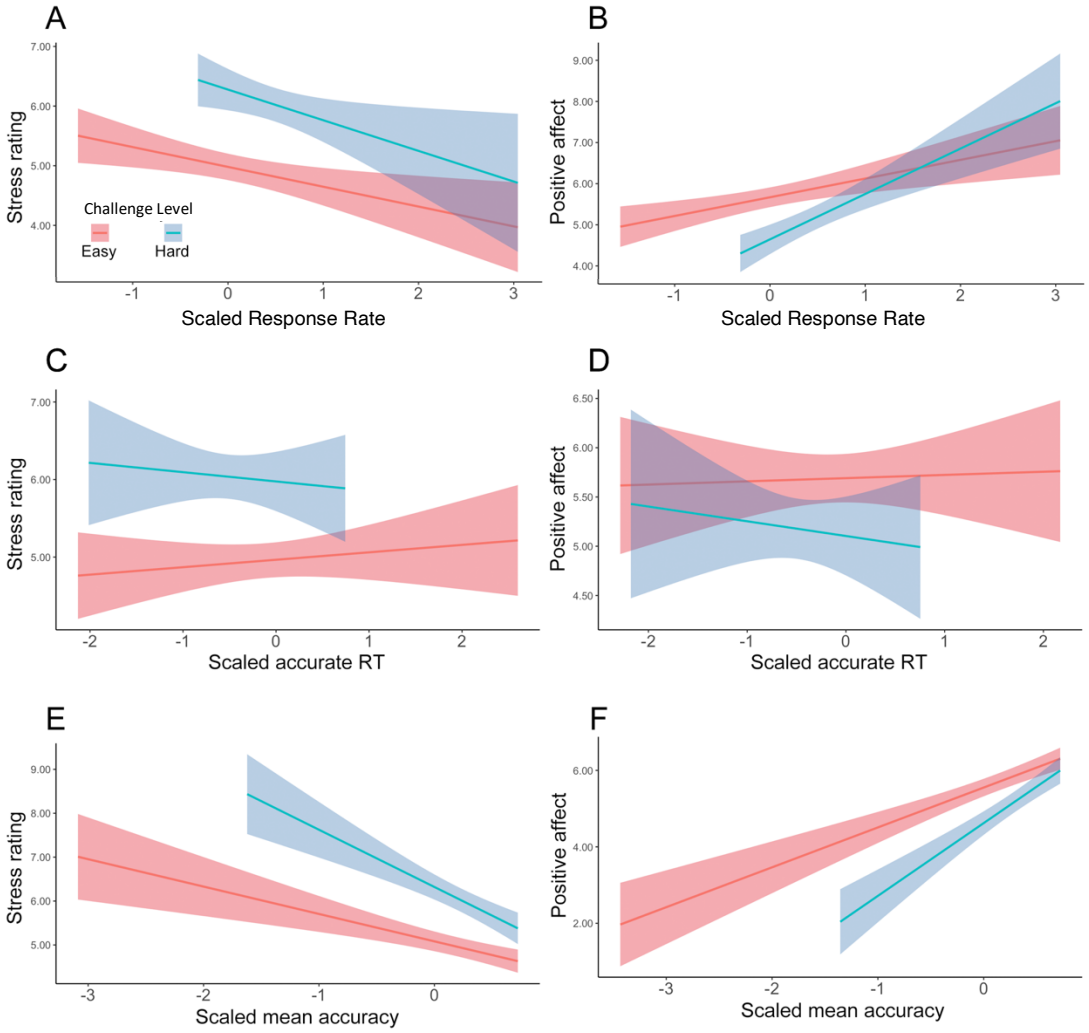

Figure 6. *Affective Ratings predicted by performance, for goal-completed intervals only (Experiment 1).* We found that in intervals where the goal had been reached, participants reported to have felt less stressed when (A) performed more correct trials per interval, (C) faster reaction time, and (E) higher accuracy. They also reported feeling better overall when (B) performed more correct trials per interval, (D) faster reaction time, and (F) higher accuracy. Error bars reflect standard errors.

Experiment 1 Discussion

Experiment 1 provided evidence that our manipulation of expected challenge level influenced performance, such that attempting to reach a harder goal motivated people to exert more cognitive effort. Though participants could have chosen to ignore the thresholds and attempt equally hard to gain as much reward bonus as possible, our results suggest that the expected challenge level of the goals do have an impact on effort exertion. Our findings over the

course of a given interval are further in line with this, with better performance both before and after goal completion, indicating that participants not only tried harder to achieve their goal in hard intervals, but also persisted with higher levels of effort after reaching that minimum goal. Taken together, these results are consistent with current work, such that a specific and challenging goal motivates the output of more cognitive effort and prolonged effort exertion compared with an easy goal.

Due to the structure of our task, we were able to examine performance with respect to the distance from the goal. We found that participants slowed down on trials near the goal while performing with similar accuracy, which could potentially indicate greater caution as they approached the goal. We also found that greater proximity to the goal interacted with challenge level to further boost accuracy on the task, potentially suggesting that closer distance to the goal provides additional motivation to complete more challenging goals relative to less challenging ones. However, we cannot rule out the possibility that participants' fatigue within each interval contributed to lower accuracy differences between challenge levels so these results should be interpreted with caution.

Our results also support the hypothesis that challenge level and performance both play a role in influencing affective experiences during the task. We found that ratings of both stress and positive affect were predominantly driven by goal completion, with less stress and higher positive affect when the goal had been completed. When focusing on the majority of intervals where participants were successful in meeting the goal, affective ratings were primarily influenced by challenge level. More challenging goals led participants to feel more stressed and less positive while performing the task, which was not mitigated by eventually reaching the goal. Interestingly, we found that performance and challenge level interacted in predicting affect, such

that higher accuracy had a larger impact on affective states when the goal was more challenging (for instance, leading them to feel greater relief at reaching one's goal), consistent with the broader claim that the effects of performance and challenge level on affective states are intertwined.

While these findings address the role of challenge level in shaping performance and affect, they leave open the question of how these variables are additionally shaped by the rewards at stake (which were held constant in this experiment). Whereas previous work suggests that higher rewards should motivate better performance on this task (Leng et al., 2021), whether these reward effects will be exacerbated or diminished by challenge level is unclear, as is the question of how reward and challenge level will separately and interactively influence affective experiences in this task. Experiment 2 sought to examine these questions by varying both the challenge level and the size of the incentives for correct performance.

Experiment 2: The integrative influence of challenge level and reward incentives on performance and affect

Methods

Participants

We recruited 79 participants online through Prolific using the same criteria as Experiment 1. Consent and IRB approval was given, and monetary reward and bonus were received for participation. One participant was excluded in the interval-level analysis due to a lack of variance in their affective ratings throughout the experiment, leaving a total of 78 participants (45 Female) for analyses, aged 18-53 (M = 27.21, SD = 8.89)

Task

In addition to varying challenge levels, we also varied reward levels in this experiment. Similar to Experiment 1, we used an interval-based task structure to measure cognitive effort persistence. In addition, participants were instructed that intervals varied in their reward values. In Low Reward intervals, each correct response earned 1 gem, whereas High Reward correct responses gave 10 gems. Therefore, the task included four conditions (Low Easy, Low Hard, High Easy, High Hard).

The task was grouped by blocks, where there were 8 blocks of 8 intervals each. Each block contained intervals with only one type of challenge level and semi-randomized reward types. Participants were again instructed that two intervals from each block would be chosen for bonus payment. Stress and positive affect were measured with the same self-reports of affective ratings as in Experiment 1. Similar to Experiment 1, we analyzed interval-level performance (correct trials per second) and self-report affective ratings by fitting linear mixed models (lme4 package in R; Bates et al., 2015) to estimate these parameters as functions of contrast-coded challenge level (Easy = -1, Hard = 1) and reward level (Low Reward = -1, High Reward = 1), and their interactions.

Results

Effects of expected reward and challenge on overall performance

Overall, participants met the minimum interval goals on 96.6% of easy intervals (average of 8.40 trials per interval) and 73.4% of hard intervals (8.67 trials) (χ^2 (1, N = 78) = 92.47, $p < 0.001$; Supplement Table 8), which were very similar to Experiment 1 (for a summary of all key findings across both experiments, see Supplement Table 10). As in Experiment 1, we also found that participants reached the higher goal threshold less often (66.9% of intervals) for easy intervals than for hard intervals (73.4%; χ^2 (1, N = 78) = 23.78, $p < 0.001$). Building on these

results, we found that participants were just as likely to reach the minimum goal for a given interval when the reward for each correct response was low (84.8%; average of 8.46 trials) as when it was high (85.1%; 8.61 trials) (p = .983). However, higher rewards motivated participants to reach the *higher* threshold more often (71.6%) than low rewards (68.7%) (χ^2 (1, N = 78) = 6.05, p = 0.019).

Consistent with Experiment 1, we found that participants completed more correct trials per second when faced with hard intervals compared with easy intervals (F(1, 77.1) = 142.53, p < 0.001; Table 10, Figure 7A), which was reflected in faster trial-wise correct responses (F(1, 73.7) = 89.13, p < 0.001) and better trial-level accuracy (χ^2 (1, N=78) = 64.62, p < 0.001). Participants also exhibited higher response rates when faced with larger potential rewards (F(1, 3975.8) = 16.83, p < 0.001). These effects of reward and challenge level on performance appear to be independent and additive, as we did not observe an interaction (F(1, 4809.6) = 0.94, p = 0.333). These results remained when controlling for whether the interval goal had been reached (Supplement Table 9, Figure 7B-C). When controlling for these variables, we found that participants were faster to complete correct trials in high relative to low reward intervals (F(1, 1238.7) = 8.29, p = 0.004) without differing in their overall accuracy (χ^2 (1, N =78) = 0.51, p = 0.635).

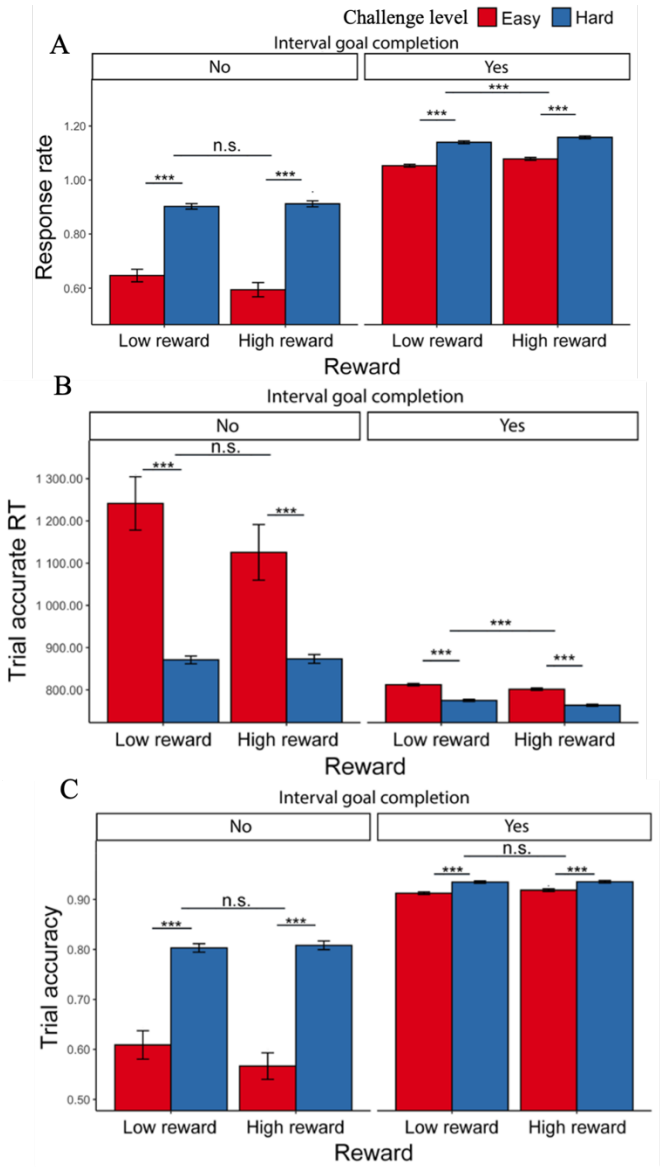

Figure 7. *Effects of challenge level, reward level, and goal completion on performance.* (A) When participants faced hard intervals and when there are higher incentives, they completed more correct trials per second. When they had reached the interval goal, we intuitively found higher response rate compared with intervals where the goal was not reached. This is reflected in both (B) faster trial-wise reaction time for correct trials and (C) higher trial accuracy. Error bars reflect standard errors. ***: $p < 0.001$

Table 10. Mixed Model Results for Correct Responses per Second Based on Challenge Level and Reward Level (Experiment 2)

Predictors	Response Rate		
	Estimates	*SE*	*p-value*
Hard - Easy	0.06	0.00	**< 0.001*** **
High Reward – Low Reward	0.01	0.00	**< 0.001*** **
Interval Goal Completion	0.41	0.01	**< 0.001*** **
Average Congruency	0.00	0.00	**0.043***
Scaled Interval Session Num	0.02	0.00	**< 0.001*** **
Scaled Interval Block Num	0.00	0.00	0.232
Challenge X Reward	-0.00	0.00	0.333

Table 11. Mixed Model Results for Reaction Time and Accuracy based on Challenge and Reward Level (Experiment 2, goal-reached intervals only)

Predictors	Response Time (for accurate trials)			Accuracy		
	Estimates	*SE*	*p-value*	*Log Odds Ratios*	*SE*	*p-value*
Hard - Easy	-32.55	3.04	**< 0.001*** **	0.22	0.07	**< 0.001*** **
High Reward – Low Reward	-5.06	1.50	**0.001*** **	0.02	0.03	0.451
Trial Goal Completion	-33.26	5.25	**< 0.001*** **	-0.19	0.03	**<0.001*** **
Scaled Trial Session Num	-36.49	8.58	**< 0.001*** **	-0.59	0.05	**<0.001*** **
Scaled Interval Session Num	23.90	8.47	**0.005** **	0.58	0.14	**<0.001*** **
Scaled Interval Block Num	-2.30	1.25	0.066	0.02	0.13	0.227
Challenge X Reward	-0.86	1.48	0.563	-0.03	0.02	0.166
Challenge X Trial Goal Completion	6.77	3.04	**0.026* **	-0.09	0.03	*0.070*
Reward X Trial Goal Completion	-0.53	2.97	0.857	0.02	0.05	0.650

Effects of goal completion and proximity on performance

As in Experiment 1, we examined effects of goal completion and proximity, focusing only on intervals in which the minimal goal was met. Similar to our findings before, participants were faster to complete trials correctly after they had reached the minimum goal ($F(1, 69.3) = 38.94$, $p < 0.001$; Table 11, Figure 8A). We similarly found that participants were faster to respond correctly in hard intervals, and, in addition, in intervals with higher potential reward, for trials both before and after completing the goal (Supplement Table 11). We observed the same main effect of challenge level on accuracy as Experiment 1 (i.e., higher accuracy for trials in the hard interval) for both trials completed before and after the goal had been reached *(ps* < .010*),* without an additional effect of reward level (*ps* > .790) (Supplement Table 12). Unlike Experiment 1, we found that participants were *less* accurate overall on trials completed after reaching the minimum goal (χ^2 (1, N = 78) = 8.26, $p < 0.001$; Table 11, Figure 8B).

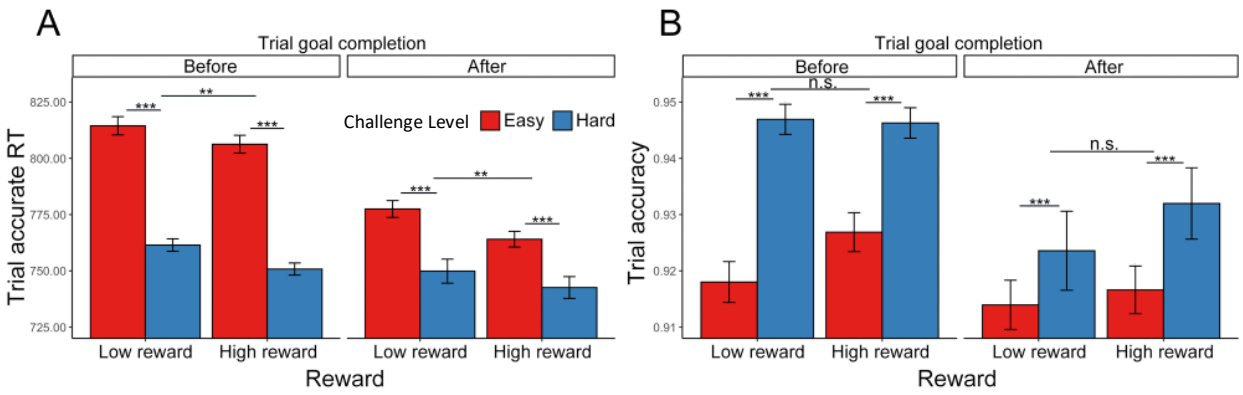

Figure 8. *Goal completion effects (Experiment 2).* (A) Participants are overall faster in completing correct trials after they had reached the interval goal. We also observed a significant interaction between challenge level and whether the goal had been reached. (B) In contrast to Experiment 1, participants were less accurate on trials completed after reaching the goal. We also observed a significant interaction between challenge level and whether the goal had been reached, such that the decrease in accuracy after reaching the goal was enhanced in hard intervals compared with easy. Error bars reflect standard errors. ***: $p < 0.001$; **: $p < 0.01$

We found similar goal proximity effects as in Experiment 1 (Supplement Table 13). As seen in Figure 9, we again found that participants initially sped up after starting the interval for approximately 2 trials, then gradually slowed as they neared and surpassed the goal. After excluding the first two trials and the last trial in each interval, we again found that participants were slower near the goal ($F(1, 124.9) = 113.82$, $p < 0.001$). We also found that accuracy decreased across conditions as participants approached the goal (χ^2 (1, N = 78) = 5.65, p = 0.012), something that we only found reliably for more challenging intervals in Experiment 1. As in Experiment 1, we also found an interaction between goal proximity and challenge level on trial accuracy, such that this decrease in accuracy was steeper for more challenging intervals (χ^2 (1, N = 78) = 4.85, p = 0.028), though again we cannot rule out explanations for this interaction related to within-interval fatigue.

Together, we found that higher reward encouraged participants to perform better and persist more with their cognitive effort, as was the case for more challenging intervals in this experiment and the previous one. Within an interval, we saw that this better performance was reflected in trials completed both before and after the goal was reached.

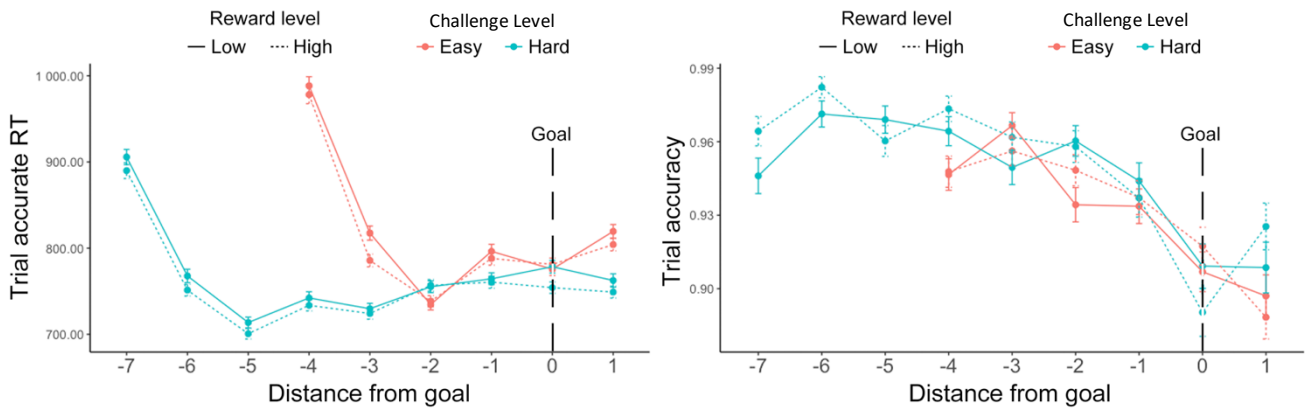

Figure 9. *Goal proximity effects in reaction time (Experiment 2).* We found similar results to Experiment 1: Overall, participants were slower when they approached the goal. Their accuracy also decreased. We again saw that participants initially sped up in performing accurate trials after starting the interval but then slowed down (at point -2 for Easy and -5 for Hard). This decreasing of speed extended until they had surpassed the goal. Error bars reflect standard errors.

Effects of reward and challenge level on affective experiences

Similar to Experiment 1, we found that participants reported feeling better ($F(1, 100.6) = 98.86$, $p < 0.001$) and less stressed ($F(1, 93.08) = 33.80$, $p < 0.001$) after reaching the goal (Supplement Table 14). Focusing on intervals where the minimum goal had been reached, participants reported higher stress ($F(1, 77.0) = 17.68$, $p < 0.001$) but no difference in positive affect ($F(1, 68.8) = 1.47$, $p = 0.140$) for hard relative to easy intervals (Figure 10, Table 12). When examining the effect of reward over and above these challenge level effects, we found that high reward relative to low reward intervals led participants to report feeling more positive ($F(1, 71.8) = 14.04$, $p < 0.001$) but *also* more stressed ($F(1, 78.8) = 11.89$, $p = 0.001$).

We also replicated Experiment 1's finding that participants reported better affective experiences (i.e., less stress and greater positive affect) with better performance, as measured by response rate, accuracy, and reaction time (Supplement Table 15-18, Figure 11). We again found that the challenge-induced affective experience (i.e., higher stress, less positive affect) was reduced as participants performed better, once again relating specifically to accuracy rather than reaction time. Examining the additional role of reward level, we found an interaction between reward and challenge level in predicting stress ratings, whereby higher reward enhanced the stress and positive affect induced by more challenging intervals (controlling for the influence of task performance; Supplement Table 15).

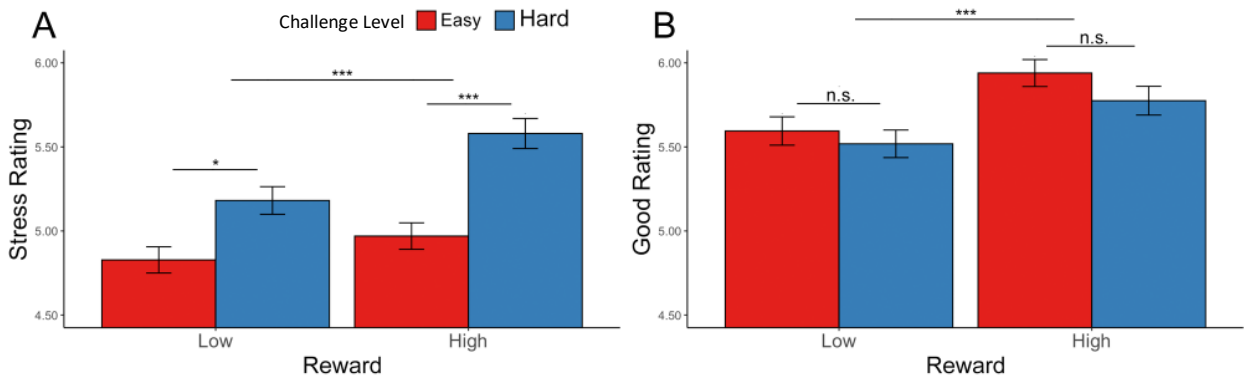

Figure 10. *Affective Ratings based on challenge level and reward level, for goal completed intervals only.* (A) Stress Ratings: Participants reported feeling more stress after completing hard intervals and intervals with higher potential reward. (B) Positive Affect: Participants reported feeling better after completing intervals with higher potential reward, but there was no difference in positive affect with respect to challenge level. Error bars reflect standard errors. ***: $p < 0.001$; *: $p < 0.05$

Table 12. Mixed Model Results for Affective Ratings Based on Challenge and Reward Level (Goal Completed Intervals Only, Experiment 2)

Predictors	Stress			Positive Affect		
	Estimates	*SE*	*p-value*	*Estimates*	*SE*	*p-value*
Hard - Easy	0.25	0.06	**< 0.001*** **	-0.06	0.05	0.140
High Reward – Low Reward	0.13	0.04	**0.001*** **	0.16	0.04	**< 0.001*** **
Average Congruency	-0.02	0.04	0.679	0.06	0.04	0.134
Scaled Interval Session Num	-0.23	0.04	**< 0.001*** **	-0.13	0.04	**0.001*** **
Scaled Interval Block Num	0.02	0.04	0.554	-0.06	0.04	0.113

Challenge X Reward	0.06	0.04	0.120	-0.03	0.04	0.491

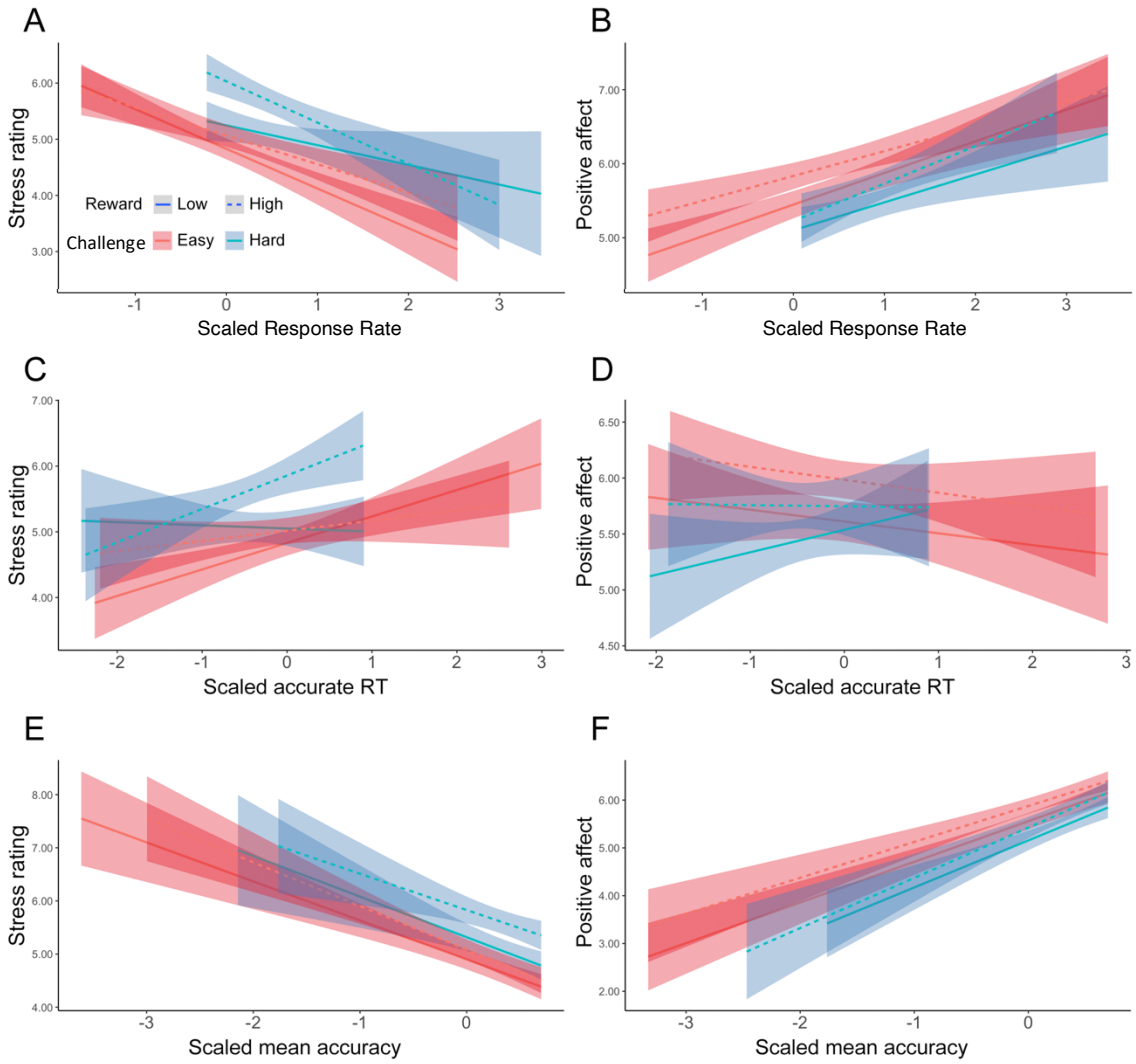

Figure 11. *Affective Ratings predicted by performance, for goal-completed intervals only (Experiment 2).* We found that in intervals where the goal had been reached, participants reported to have felt less stressed when (A) performed more correct trials per interval, (C) faster reaction time, and (E) higher accuracy. They also reported feeling better overall when (B) performed more correct trials per interval, (D) faster reaction time, and (F) higher accuracy. While we found that challenge level interacted with response rate and accuracy in predicting positive affect, there was no interaction of reward with performance. Error bars reflect standard errors.

Experiment 2 Discussion

By varying reward level in addition to challenge level, we were able to show that both variables motivate better performance, with participants completing more correct trials per

interval with higher levels of expected reward and challenge, respectively. Within intervals, the speeding effect of goal completion on reaction time largely replicated that in Experiment 1, with higher rewards also exerting an additive rather than interactive influence on those RTs over and above the influence of challenge level. However, the effect of goal completion on accuracy was reversed in Experiment 2, such that participants were less accurate after completing the goal, and more so for harder intervals. This potentially reflected a lowered threshold for responding (altered speed-accuracy tradeoff) closer to the end of the interval, especially in the case of hard intervals where post-goal trials mean participants have less time left than on easy intervals. We largely replicated the effects of goal proximity here, such that participants performed the task more slowly as they approached the goal, and in this experiment additionally found that they were less accurate as they approached the goal.

We found that higher levels of expected reward, like higher levels of expected challenge level, induced greater stress, while also contributing to greater positive affect when the participant met their goal. Unlike Experiment 1, we did not find an effect of challenge level on positive affect, potentially indicating that the inclusion of a reward manipulation changed how challenge level contributed to these appraisals. We again found that better performance, particularly reflected in higher accuracy, predicted feeling more positive and less stressed.

Discussion

We engage in effortful control to reach goals constantly. The amount of control invested depends on motivation to achieve the goal, which is determined by factors such as performance incentives and task demands. The current work investigated the role of expected challenge and reward level on effort exertion and persistence in a cognitively demanding task, as well the affective experience associated with performing the task. Overall, participants were motivated to

allocate more cognitive effort, and prolong persistence of effort, when faced with more challenging goals and higher potential rewards, resulting in better performance on the task. Participants experienced greater stress when performing under greater challenge and/or higher stakes, but these experiences were accompanied with greater positive affect when the stakes were high, and when the participant performed well during that interval (which also mitigated stress levels).

Task performance varies with challenge, reward, and goal proximity

The relationship we found between challenge level and task performance confirm a central prediction of the goal setting theory, that more challenging goals lead people to work harder. As Locke et al. (1981) found, more challenging goals produce better performance because people exert more effort to complete it. This is reflected in our study, as both of our experiments found that participants completed more correct trials per interval in more challenging intervals, even though individual trials were rewarded *equally* across easy and hard conditions. Results from our Experiment 2 additionally pointed to monetary incentives as a motivator of performance and goal attainment, which is consistent with past work on goal setting theory and research on the incentivization of cognitive control (Botvinick & Braver, 2015; Wright, 1992).

The goal threshold and timed-interval design of our study also allowed us to examine how effort persistence is influenced by challenging goals. Because participants are free to choose how many trials they want to perform within these fixed time intervals, they could have chosen to stop exerting effort once the goal had been reached, or even prior to reaching the goal if they found it too taxing or impossible to reach. However, our results show that participants not only continued to perform more trials after reaching the goal, but they were also faster to complete

trials correctly (and, in Experiment 1, also more likely to respond correctly) after the goal had been reached. In both experiments, we found that this speeding after goal-completion was larger when participants faced more challenging goals. Therefore, our results support that adequate expected challenge prolongs cognitive effort persistence, and even enhances effort exertion, especially when the task is more challenging.

Across both experiments, we found that participants slowed down as they neared the goal, indicating more cautious behavior as they approached goal completion. Interestingly, we found that participants initially sped up in performing accurate trials after starting the interval but then slowed down. The distinct patterns of speeding and slowing over the course of the interval, could reflect dynamic reconfigurations of control across information processing (e.g., enhancing the accumulation of incoming evidence) and response thresholds (Grahek et al., 2023; Ritz et al., 2021). Follow-up studies could examine this possibility by using sequential sampling models (e.g., the drift diffusion model) to separately estimate the corresponding model parameters (Leng et al., 2021) at different stages within an interval.

Affective experiences vary with challenge, reward, goal attainment, and performance

Goal attainment has been found to be related to satisfaction and well-being (Parker et al., 2009). In our study, goal attainment promoted greater positive affect, as did the prospect of gaining higher monetary reward. We also found that failure to attain a goal led to higher stress. Interestingly, our results indicate that the effects of goal attainment on affective experience are additionally impacted by challenge level, as harder challenge led participants to feel more stressed and less positive affect, despite having completed the task goal. Higher reward, on the other hand, paradoxically led to higher stress and greater positive affect. This could reflect dual appraisals of the rewards at stake in terms of their consummatory value as well as the potential

opportunity cost for completing fewer trials than one is able (Shenhav & Buckner, 2014). Therefore, more potential reward would cause more stress during task performance, but also lead to greater satisfaction when received. Whether participants are framing these stakes as potential losses, and if this framing has any effect on behavior, is worth exploring in future studies (cf. Prater Fahey et al., 2023).

The effects of goal attainment on affective experience were influenced by how much effort the participant had put into the task, as measured by response rate, average reaction time, and average accuracy. Across both experiments, participants felt more positive and less stressed when they had exerted greater and more prolonged cognitive effort to achieve better performance and had reached their goals. Interestingly, in Experiment 1, we also found that expected challenge level interacted with performance in predicting affective ratings – performing well had a more salutary effect on affect (greater increases in positive affect and decreases in stress) for hard than easy intervals. This suggests that when participants view a task as more challenging, they place more value in the effort they exerted (Inzlicht et al., 2018). Notably, this interaction effect was only found with task accuracy and not reaction time, suggesting that affective experience might be selectively attached to how accurate the performance was rather than simply how fast they are performing. Taken together, our results suggest that participants' experiences of stress and positive affect not only take into account the end result, but also the process and intrinsic motivation that led there.

Limitations and Future Directions

Our task relies on self-report measures of affective experiences, measured repeatedly throughout the experimental session, at the end of each interval. In spite of its benefits, this approach risks eliciting demand characteristics related to inferences of what affective ratings we

as experimenters believe to be relevant to the different experimental conditions. Conversely, giving these ratings may diminish participants' affective experiences (Kassam & Mendes, 2013; Torre & Lieberman, 2018). Future studies could aim to incorporate physiological measures of acute stress (e.g., skin conductance, EKG) for a more well-rounded perspective.

Our goals were also uniform across participants, always requiring 5 correct responses for easy intervals and 8 correct responses for hard intervals. Though we chose these thresholds based on their ability to generate intervals that were generally achievable for the majority of participants, but differing in the effort required to meet that challenge, the absence of individualized goals meant that the level of challenge and achievability likely differed across participants. Future studies should aim to calibrate these thresholds to a given participant. Additionally, because of the overall high goal completion rates in our data, we had insufficient intervals to tease apart the behavioral strategies that resulted in participants failing to reach their goal. For instance, it could be that failures to reach a goal reflected intervals where the participant was trying to meet the goal but felt unable to meet the challenge, for example due to capacity limitations or fatigue. Alternatively, failure to reach the goal could reflect slacking rather than an inability to achieve the goal, especially when these failures occurred for easy intervals, where participants generally performed near ceiling in terms of goal attainment. These two types of goal failure can yield different patterns of performance and affective experience, and future work should aim to disentangle these.

In conclusion, our study provides evidence that more challenging goals lead people to work harder but to also experience greater stress doing so, and that promising greater rewards lead to an enhancement rather than diminution of both of these effects. The wide application of goal setting theory and the influence of challenge level in fields such as education and industry,

in motivating students and workers to perform their best, prompts more extensive studies on this topic. Focusing especially on how acute stress, resulting from the goal, task, and potential reward, plays a role in effort motivation is important not only in promoting performance, but also in ensuring the mental health and well-being of those who are completing the tasks.

Acknowledgements

This research was supported by an NIH T32-MH115895 (X.L.) and an NSF CAREER Award 2046111 (A.S.). We are grateful to Mahalia Prater Fahey, Debbie Yee, and Amanda Arulpragasam for helpful discussions and feedback.

Author contributions

This study was conceived by Y.Z. and A.S., the task was programmed by Y.Z. and X.L., and the data were collected and analyzed by Y.Z., under the supervision of X.L. and A.S. Y.Z. drafted the manuscript and all authors contributed to revisions.

Ethics approval

Approval was obtained from Brown University's Institutional Review Board. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Conflicts of interest/Competing interests

The authors have no relevant financial or non-financial interests to disclose.

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