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BRIEF REPORT

From Action Initiation to Persistence: A Pavlovian-to-Instrumental Transfer Analysis for Cue-Based Goal Pursuit

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Previous research suggests that cues can motivate goal-directed behavior directly. According to the framework of human unconscious goal pursuit, exposure to goal-relevant cues yields two distinct behavioral effects: action initiation and subsequent action persistence. However, the evidence for such a full motivational control effect in human goal-directed behavior is meager. The present study builds on the Pavlovian-to-instrumental transfer (PIT) approach to test the cue-based motivational control. We employed a tapping task that considers the speed of decreasing the distance between an outcome and oneself as an index of motivation of behavior. Thus, we could separate action initiation and persistence in one single test task. Participants first underwent instrumental and Pavlovian training. They learned to press two keys to earn 20 or 5 cents (high- or low-value outcomes) and to associate the two outcomes with two specific cues. Next, they had to press one of the two keys multiple times to bring a Pavlovian cue to the front of their computer screen. Results showed that participants responded faster with the high-value key to the high- versus low-value cue, indicating value-sensitive action initiation effects. However, this effect did not translate into action persistence, as the response time steeply declined over time. These results point to the importance of differentiating between action initiation and persistence of action in cue-based goal-directed behavior as modeled by PIT.

Keywords: pavlovian-to-instrumental transfer, goal-directed action, action initiation, action persistence

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The environment serves as a strong motivator for people to engage in goal-directed behavior. According to the framework of unconscious goal pursuit (Custers & Aarts, 2010), exposure to goal-relevant cues has two behavioral effects. First, the cue triggers goal-directed action because of a habitual link between cue, goal, and action. For example, upon seeing an empty glass, a person readily walks to the refrigerator to get a soft drink. Once the goal-directed habitual response is triggered, the rewarding value attached to the goal motivates the individual to attain the goal. For example, if the refrigerator door is stuck when opening it, the person must pull harder to access the drink. Thus, the full motivational nature of goal-directed behavior comprises two successive components: action initiation—that is, the speed of selecting appropriate actions in response to goal-relevant cues and action persistence—that is, the amount of effort invested in maintaining behavior to achieve the goal (Aarts et al., 2004; Geen, 1995; Gollwitzer, 1999).

There is evidence that cues can trigger goal-directed behavior. However, it is unclear whether such environmental control speaks to the full motivational nature of goal-directed behavior (Aarts et al., 2008; Marien et al., 2019). The present study addresses this question by relying on a task that separates the speed of action initiation and persistence in one learning context.

An experimental method to study cue-based motivational control over behavior is the Pavlovian-to-instrumental transfer (PIT) test. In the PIT paradigm, participants undergo instrumental and Pavlovian learning. They acquire relations between responses and rewarding outcomes and between stimulus cues and the outcomes. The cue and response thus share the same outcome. Evidence for a specific PIT effect is provided when the Pavlovian cue triggers the instrumental response that leads to the same outcome, especially when the outcome has value for the participants (Cartoni et al., 2016; Holland, 2004; Jeffs & Duka, 2017; Mahlberg et al., 2021). The observation that the specific cue triggers the specified action without any direct sensorimotor experiences between the action and cue indicates the mediating role of the cognitive representation of the specific desired outcome. Accordingly, the value-driven PIT effect is considered to model

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cue-based motivational control over goal-directed behavior (e.g., Dickinson & Balleine, 1994; Mahlberg et al., 2021).

Previous studies examined different tests of cue-based control of behavior (Allman et al., 2010; Qin et al., 2021; Seabrooke et al., 2019). PIT has been tested on decision-making, showing that people are more likely to choose actions in response to cues associated with outcomes of actions (e.g., Jeffs & Duka, 2017) or on forced-choice response time tasks (Qin et al., 2021; Watson et al., 2016), showing faster response initiation to cues that represent valuable outcomes. Research also employed handgrip tasks to assess people's efforts to obtain rewards, but the results are mixed (Chillà et al., 2019; Lehner et al., 2017).

The present study takes a different approach. Rather than testing PIT effects on action initiation and persistence in different tasks, we measured them simultaneously in one single task. We used the measure designed by Marien et al. (2015) that operationalizes the motivational nature of goal-directed behavior as the speed of decreasing the distance between the outcome and oneself, one of the hallmarks of goal-directed motivation (e.g., Carver & Scheier, 1998). Marien et al. (2015) devised a task where participants could bring an object that had value or not to the front of the computer screen by tapping 20 times on a key. They reasoned that initiating tapping is relatively easy, while persisting in subsequent tapping requires effort. Hence, tapping speed should decrease less rapidly when motivated to move the object to oneself. Participants were faster to initiate action when objects represented valuable outcomes. Importantly, a linear test of the remaining 19 taps showed that subsequent tapping in response to outcome-related (vs. no outcome-related) objects slowed down less steeply. Thus, while the speed of action initiation was goal-directed, the persistence of engaging in it revealed the full motivational nature of outcome value.

We adapted the forced-choice response time task (Qin et al., 2021) to study PIT effects. Participants learned to press two different keys to gain high (and low) value rewards. They also learned to associate the rewards with two different cues. Thus, the cue and response share the same outcome, while the response and cue do not directly co-occur. In a final test, they had to bring the cues to the front of the computer screen by tapping one of the two keys repeatedly in response to the cues. If the PIT effect is value-driven, the cue associated with high-value (vs. low-value) rewards motivates the high-value reward response, while such motivational effects are not expected to occur for the low-value reward response. In line with Qin et al.'s (2021) study, we predicted that participants would initiate the high-value response when exposed to the high (vs. low) value cue, while this cueing effect should be absent for the low-value response. Furthermore, if the effect on action initiation persists over time, the speed of remaining taps for high-value responses should decrease less rapidly in response to the high (vs. low) value cue, while tapping the low-value response would slow down quickly irrespective of cue values.

Method

Participants and Design

The sample size was determined by a simulation-based power analysis (Lakens & Caldwell, 2021) to replicate the previous study (Qin et al., 2021) with 99% power. The simulation indicated that 77 participants were needed. We aimed to recruit 50% more participants considering the possible dropout. We recruited 116 participants and excluded one participant because of data transmission failure. Furthermore, the data of 12 participants were excluded because they reported either incorrect learning of response–outcome relationships or cue–outcome relationships. The data of the remaining 103 participants (55 men; $M_{\text{age}} = 24.97$ [$SD = 6.25$]) were subject to a 2 (response outcomes: low- vs. high-value) × 2 (cue outcomes: low- vs. high-value) within-participants design.[1] Participants received a fixed amount of £2.50 as participating fee and could earn extra money (up to £2.28) depending on performance during the task.[2] This study received approval from the Ethics Review Board (approval code: FETC20-409).

Procedure

Demonstration Phase

Participants performed 20 randomly presented demonstration trials to familiarize them with the procedure of the test phase described below.

Instrumental Learning Phase

Participants had to press the correct key 20 times to collect a coin (see Figure 1A).[3] In each trial, participants saw a hallway background and a coin in the middle, moving to the front of the screen after each keypress. Trials started with a gray square presented for 1–3 s (random time interval), then a colored frame (a blue or a yellow frame) appeared until participants responded. At that moment, participants could earn 5 cents by pressing the (left) "w" key in response to the yellow frame. After the first keypress, they saw a 5 cents coin. However, they needed to press the same key 19 times further to collect the 5 cents coin. Likewise, they could earn 20 cents by pressing the (right) "o" key in response to the blue frame (colored frames were counterbalanced across participants) 20 times in a row. To encourage participants to process the outcome information carefully, they were asked to speak out "5 cents" or "20 cents" upon the first response, depending on the particular response–outcome mapping. Participants first engaged in 20 practice trials and then moved to the 20 actual trials. They were told the coins would be cashed out in 50% of the actual trials (five times 5 cents and five times 20 cents). If they pressed an incorrect key, a red cross was displayed for 1 s, followed by a blank screen for 1 s. At the end of the phase, they received information about their extra earnings, up to €1.25.

Pavlovian Learning Phase

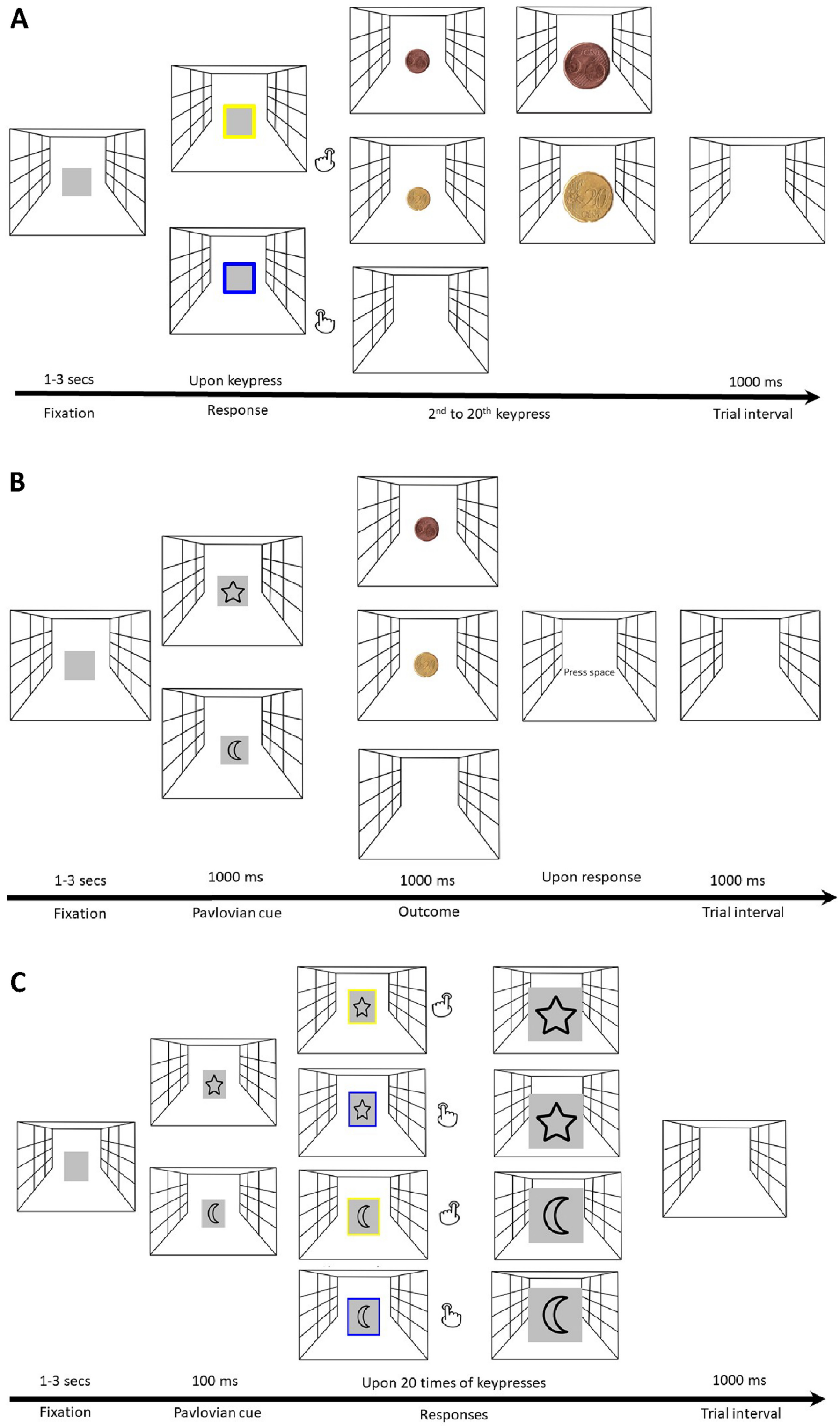
Trials (Figure 1B) started with a gray square shown in the screen center for 1–3 s (random time interval). Then, a "star" or a "moon"

[1] We conducted a sensitivity analysis to reveal the minimum effect size that could reliably yield a statistically significant result (Perugini et al., 2018). The results indicated that the study had 80% power to detect an effect size of at least $f = .14$ (transformed to $\eta_p^2 = .02$) in the two-way within-factors interactions.

[2] We used euro cents as outcomes but still paid participants with pounds after the currency exchange because participants can only be paid in pounds in Prolific.

[3] We collected data from the Instrumental learning phase. The relevant analyses will not be further discussed but can be found in the online supplemental materials. The verbatim instruction for the experiment can be found in OSF: https://osf.io/b2zxg/?view_only=adda27f0bc174e55b1041e61dcc53b87

Figure 1
Flowchart of Correct Responses in Instrumental Learning Task (A), Pavlovian Learning Task (B), and Transfer Task (C)



Note. See the online article for the color version of this figure.

appeared for 1 s. Like in the instrumental learning phase, participants received 5 cents and 20 cents. There was a practice and actual task where they spoke out “5 cents” or “20 cents” when they saw a “star” or a “moon” (the particular stimulus–outcome mapping was counterbalanced across participants). The task started with 20 practice trials, followed by 20 actual trials. Participants were told that the coins would be cashed out in 50% of the actual trials (five times 5 cents and five times 20 cents). The next trial started after participants pressed the space key, followed by a blank screen for 1 s. At the end of the phase, they received information about their extra earnings, which were €1.25.[4]

Test Phase (Hallway Task)

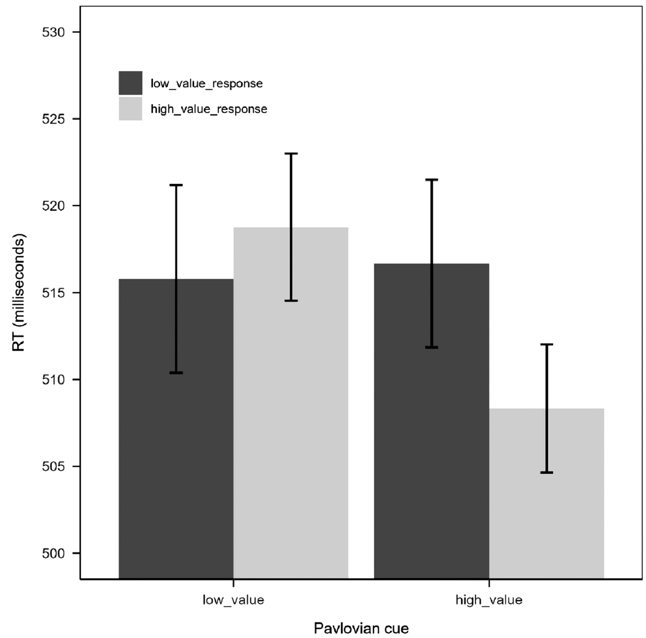
Participants performed 40 randomly presented trials, and each condition (i.e., high- vs. low-value responses × high- vs. low-value cues) was repeated 10 times (see Figure 1C). In this task, one of the two cues (a “star” or a “moon”) appeared in the middle of the hallway. After 100 ms, a yellow or blue frame of a square surrounded the cue to prompt the “w” (left) or the “o” (right) response (counterbalanced). Upon seeing the prompt, participants pressed the respective key 20 times to finish the trial. Once participants had pressed the correct key, the colored frame disappeared, and tapping continued for another 19 times to move the cue to the front. If participants initiated a wrong response, a red cross appeared for 1 s, and only the hallway background appeared for 1 s. After each key press, the cue was increased by 12.5 pixels, and the impression was created that the cue was brought closer to the participant. The 20th key press caused the cue and the hallway to disappear, meaning participants had collected the cue, and a blank screen was presented for 1 s. Note that participants did not earn any coins in this task.[5]

Following Marien et al. (2015), the response latency of the first keypress represents action initiation, and the response latencies of the subsequent 19 key presses are an index for action persistence.[6]

Data Preparation and Analysis

The data preparation and analysis are the same as Qin et al. (2021). We trimmed the first response reaction times (RTs) of the correct responses in the test phase for outliers as in previous research (Qin et al., 2021; 5.0% of the RT data). We removed the second to the 20th response RTs that were either incorrect or faster than 60 ms (Pinet et al., 2017) or slower than 3 *SD*s of the participant’s mean (4.9% of the second to the 20th response RT data). Then, we applied a reciprocal transformation to the first response RT data, the remaining RT data, and the accuracies.[7] We performed a planned contrast for the whole data using an *F*-test and reported partial eta squared (η_p^2) as effect size with a 90% CI (Furr & Rosenthal, 2003; Rosenthal & Rosnow, 1985). We predicted that the first response RTs pattern should replicate the action initiation effect found in the previous study (Qin et al., 2021). More specifically, participants should respond faster when the cue and the response predict the same outcome, and this effect should be more pronounced in the high-value (20 cents) cue condition. The coding weight for each cell of the contrast was as follows: −1 for the 5 cents response/5 cents cue cell, +2 for the 20 cents response/5 cents cue cell, +2 for the 5 cents response/20 cents cue cell, and −3 for the 20 cents response/20 cents cue cell (see Qin et al., 2021). The analyses of the remaining 19 response latencies followed the same contrast but included a linear test to inspect differences in steepness over time (Marien et al., 2015).

Figure 2
Reaction Times Pattern of the First Response in the Test Phase



Note. Error bars represent one standard error of the mean. All presented figures’ error bars have been corrected based on adjusted values for taking within-subject variances into account (Morey, 2008). RT = reaction time.

Results

RTs of the First Response

The RTs pattern of the first response is presented in Figure 2. The planned contrast was significant, $F(1, 102) = 5.67$, $p = .019$, $\eta_p^2 = .05$ [0.005; 0.138], indicating that participants responded faster

[4] We decided to give all participants the same amount of extra money (i.e., €1.25) in this phase because we did not collect any response data in this phase.

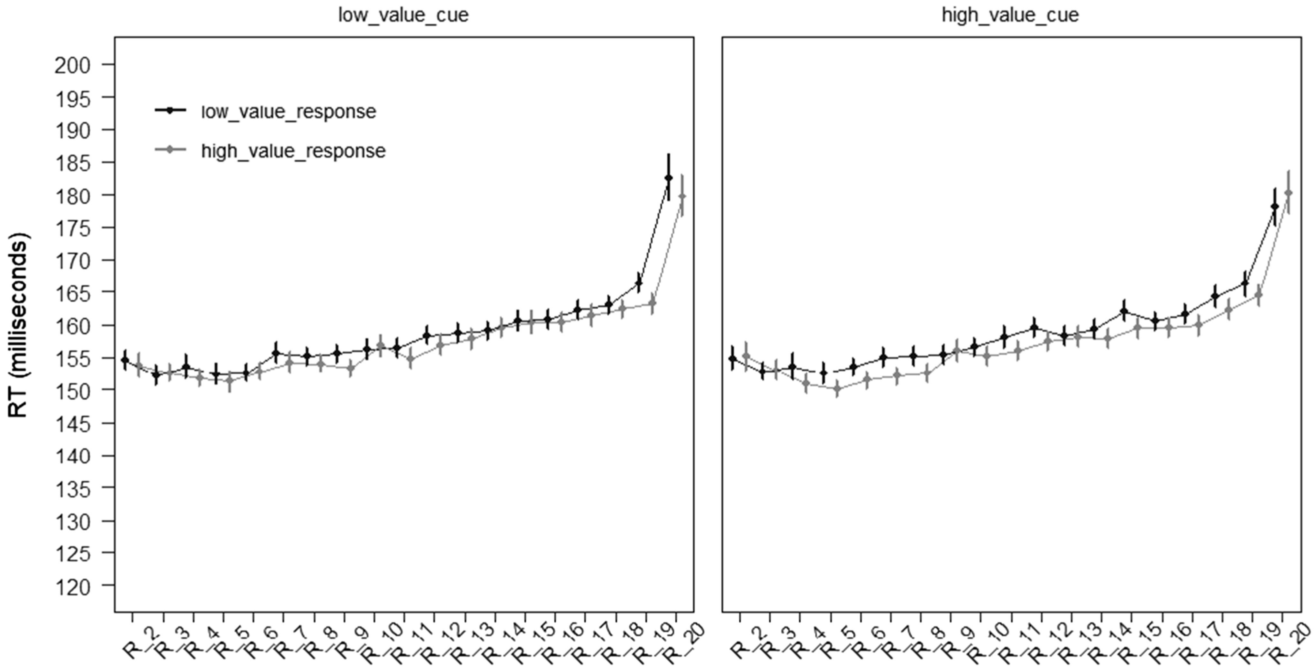
[5] After the test task, four manipulation checks were administered to assess whether participants correctly recalled the response–outcome and stimulus–outcome associations (see the online supplemental materials). In the end, a questionnaire assessed experiences of the task (this is not further discussed in the paper; descriptions can be found in the online supplemental materials).

[6] The method is based on a previous experiment that yielded null results (more details in the online supplemental materials). We reasoned that the null results were mainly due to flaws in the instrumental learning phase that did not contain the hallway task. We, therefore, included this feature in the current experiment.

[7] We did the transformation because these data were not normally distributed (see the details in the online supplemental materials). Although we used transformed data in the analyses to clarify the predicted pattern, figures of the RTs and the accuracies in both experiments were presented with untransformed data. The figures with transformed data can be found in the online supplemental materials. Analyses of accuracy data can be found in the online supplemental materials as well.

Figure 3

Reaction Times Pattern of the Remaining Key Presses in the Test Phase



Note. Error bars represent one standard error of the mean. The *x*-axis represents the number of presses in the test phase. RT = reaction time.

when the cue and the response predicted the same outcome, and this effect was more pronounced in the high-value cue condition.[8]

RTs of the Remaining Responses

The analyses showed that the contrast was not significant, $F(1,\ 102) = 0.43$, $p = .516$, $\eta_p^2 = .00$ [0.000; 0.049]. The linear effect of the remaining responses was significant, $F(1,\ 102) = 145.73$, $p \leq .001$, $\eta_p^2 = .59$ [0.490; 0.664], indicating that participants gradually slowed down their speed when finishing each trial. The effect of the contrast by the linear effect was not significant, $F(1,\ 102) = 0.51$, $p = .477$, $\eta_p^2 = .00$ [0.000; 0.051]. Figure 3 presents the RTs pattern of the remaining keypresses.

Discussion

The present study examined the full motivational nature of cue-based goal-directed behavior by designing a test task that exploits one of the hallmarks of goal-directed motivation: The speed of decreasing the distance between rewards and oneself (e.g., Carver & Scheier, 1998). Specifically, we used the speed of the first response and the 19 remaining responses as an index of action initiation and persistence, respectively. We found that first responses were faster when the cue and the response predicted the same high- versus low-value outcome, replicating earlier findings (Qin et al., 2021). However, no effect occurred for the remaining responses. Within our experimental setup, the results suggest that cues associated with rewards facilitate initiation but not the persistence of goal-directed behavior.

It should be noted that our current experimental task deviated from the standard PIT paradigm used in basic research (Qin et al., 2021) to create an RT task. Despite this, we note that the obtained effect on RTs is still likely caused by PIT based on value. As Pavlovian cues and actions were never directly presented together during learning, the effect cannot result from the reinforcement of stimulus–response associations. Accordingly, the representations of the valued outcomes must have mediated the response facilitation effect of Pavlovian cues.

The null effect on persistence may indicate that despite facilitating the initial response, participants did not spend additional effort to obtain the cues. Research on the behavioral, neurophysiological, and computational implementation of effort suggests that effort investment is subject to resource conservation: Individuals avoid wasting energy and invest resources only for outcomes that are attainable and valuable (Bijleveld et al., 2012; Brehm & Self, 1989; Chong et al., 2017; Gendolla & Richter, 2010; Lopez-Gamundi et al., 2021). In our test task, the cues were associated with rewards but did not serve as real outcomes. It might, therefore, not have been worthwhile to spend effort responding to the cues. Accordingly, the absence of the persistence effect stems from the specific nature of the operation of outcomes in our task. Interestingly, previous animal research suggests that cues associated with rewards can motivate themselves (Brown & Jenkins, 1968; Williams & Williams, 1969). Future research could address more precisely how cues can facilitate effort in human goal-directed behavior.

[8] We also tested the unbiased contrast (1, −1)–(1, −1) to assess whether the significant effect depended on the use of a contrast biased by the difference in the strength of the 20 cue condition. This unbiased contrast was also significant; $F(1,\ 102) = 4.55$, $p = .035$, $\eta_p^2 = .04$ [0.002; 0.123].

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