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Environmental Control of Human Goal Pursuit: Investigating Cue-Based Forced Responses in a Pavlovian-to-Instrumental Transfer Paradigm

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Effective human action is dependent on goals that are cued in the environment. A major challenge in examining the environmental control of goal-directed behavior concerns a proper test of the mediating role of outcome value in cue-driven behavior. Building on the Pavlovian-to-instrumental transfer (PIT) paradigm, in two experiments we tested a novel forced-choice multiple response task that allowed us to test specific PIT effects by analyzing RTs and accuracy. We hypothesized and found that a Pavlovian cue that was predictive of low or high valued outcomes triggered instrumental responses when the cue and response shared the same outcome compared to when the cue and response did not share the same outcome. Importantly, these effects were more pronounced for high (vs. low) value outcomes, suggesting a value-based specific PIT effect. Theoretical implications and future directions for this novel PIT paradigm are briefly discussed.

Keywords: Pavlovian-to-instrumental transfer, RTs, value, goal-directed behavior, forced-choice

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Human behavior is directed at attaining goals. The goals that people pursue can be associated with environmental cues. Hence, goals and subsequent behavior can become activated when people encounter these cues. In that sense, cues are essential in evoking and maintaining human behaviors (Chartrand et al., 2008; Custers & Aarts, 2010; Mowrer & Jones, 1945; Wickens & Platt, 1954). For instance, when a smartphone vibrates, this can be a cue for a person to pursue the goal to socialize, resulting in reaching for the phone to read one's friend's messages (Brown et al., 2016). Some cues are strong incentives that enhance people's motivation to engage in goal-directed behavior. Whether such behavior is instigated by the anticipation of a goal or by the cue–behavior association is still unclear, because most research is ambiguous about the role of value in action-outcome representations (Custers & Aarts, 2005; Marien et al., 2015; Watson et al., 2018; Weingarten et al., 2016). Much of the unclarity stems from the test methodology of human behavior research where the role of cues is often tested in free-choice settings that target decision making processes and do not specifically target goal-directed behavior. Building on research examining the role of instrumental and Pavlovian learning in goal-directed behavior (Dickinson & Balleine, 1994, 1995), we present a test of a novel forced-choice multiple response task that targets the process underlying environmental control of human goal pursuit.

A central assumption in research on goal-directed behavior is that people represent their actions in terms of outcomes. The anticipation of these outcomes causes people to perform the associated actions (Shin et al., 2010; Suddendorf & Corballis, 2007). There is general agreement that cues control behavior in a goal-directed manner by triggering responses through the mediation of outcome representations. However, testing this is a challenge, because one needs to rule out that behavior is driven by a direct cue-behavior link. One well-accepted method to demonstrate this is to separate response-outcome learning (instrumental learning) from cue-outcome learning (Pavlovian learning). In this method, the Pavlovian cue shares the same outcome with the response that is instrumental in obtaining the outcome, but there is no direct relation between the Pavlovian cue and the response. Thus, when the cue can trigger the response, this suggests that this happened through the shared outcome. This demonstration of an indirect link between cue, outcome, and behavior is termed Pavlovian-instrumental transfer (Holmes et al., 2010; hereafter abbreviated as PIT).

Although the PIT paradigm was first used in research on animal learning, recently, PIT effects have been addressed in research on human behavior. Typical PIT studies require participants to display responses (e.g., pressing a key) that produce rewards (e.g., snacks) more frequently when a Pavlovian cue is presented that predicts the rewarding outcome compared to when a cue is presented that does not predict any desired outcome (Lehner et al., 2017; Lovibond & Colagiuri, 2013; Lovibond et al., 2015; Seabrooke et al., 2017; Talmi et al., 2008). This supports the general notion that cues facilitate human actions through outcome representations. To further address whether cues only trigger those responses that are distinctly directed at particular outcomes, researchers use specific PIT paradigms.[1] Specific PIT is a valuable tool to investigate the goal-directed nature of cue-driven behaviors in humans. In particular, the PIT effect should be dependent on the current value of the outcome (Watson & de Wit, 2018).

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[1] PIT studies generally employ three sub-categories: non-selective PIT, general PIT, and specific PIT (Holmes et al., 2010; Mahlberg et al., 2019). Specific PIT paradigms are designed to test goal-directed behavior.

Most human studies measure preferences for response options to test specific PIT effects. For instance, Watson et al. (2016) used a free-choice task to test adolescents' preferences for responses that were learned to gain either high or low caloric food rewards. When Pavlovian cues were presented that predicted high caloric food, participants preferred to press the key associated with high caloric food. Pavlovian cues associated with low caloric food did not bias preferences toward responses gaining low caloric food. Assuming that higher caloric value means higher incentive value (Tang et al., 2014), these findings suggest that value moderates the specific PIT effect. However, the reaction time (RT) data were less clear. While the RT data of the first experiment demonstrated that the specific PIT effect is stronger in the high value condition, the RT data of the second experiment were not in line with these expectations (Watson et al., 2016). Specifically, high caloric food cues evoked slower responses compared to low caloric food cues, indicating a reversed specific PIT effect. Apparently, freely selecting options that lead to high value outcome takes more time, likely to prevent oneself from missing out on the desired option.

Another recent free-choice test used monetary rewards to test the role of outcome value in PIT (Jeffs & Duka, 2017). In this study, participants learned to associate two different keys with two different monetary rewards (i.e., 10 cents vs. 50 cents coins). Specific PIT effects were assessed by testing choice in response to Pavlovian cues that predicted the low versus high monetary rewards. A strong response outcome-cue effect was found; cues considerably increased response choice (up to 90%) of the specific key related to the specific monetary outcome. This effect was more pronounced for participants who were aware of the Pavlovian cue-outcome association. However, the effect was not moderated by the reward value of the cue, indicating that the test could not differentiate between outcomes that are more or less important. Whereas we do not know whether the substantial outcome-response bias in choices represents strategic task behavior resulting from demand characteristics, strong explicit expectations might have obscured the outcome value-based specific PIT effect.

In sum, findings in the current literature on cue-based goal-directed behavior in humans do not paint a clear picture of the role of reward value. We argue that although the Pavlovian cues do seem to have the potential to evoke goal-directed responses, how the responses are triggered in these studies is open to disturbances from free choice and task-strategic processing. The present study aimed to circumvent this issue by excluding the possibility of free choice, which is the classic test methodology in PIT research. Instead, we designed a novel PIT test that employs a forced choice speeded task.

Forced choice tasks provide the opportunity to test the influence of cues by creating response conflict situations, as is typically done in flanker and Simon tasks (e.g., Simon & Acosta, 1982). The logic is simple: When a cue triggers a response that is different from the one required by the task, a response conflict arises that needs to be resolved. Thus, integrating PIT research with forced-choice speeded tasks allow us to test how strong specific responses (e.g., pressing left or right) that are associated with a specific outcome (low vs. high value outcome) are evoked by the Pavlovian cues that share these outcomes. In particular, when a cue is presented that predicts an outcome of high value, this would potentiate the response associated with that same high value. Consequently, Pavlovian cues that represent high value outcomes should trigger compatible responses that are specifically linked to these outcomes more quickly and more accurately than incompatible responses linked to a different outcome. Such a response compatibility effect should be weaker in response to Pavlovian cues that represent low value outcomes. Accordingly, we test the hypothesis that cues associated with high values trigger responses more strongly than cues associated with low value.

For this purpose, we designed an experimental set-up that consisted of three phases. First, in an instrumental learning phase, participants press a specific key (left or right) to obtain an outcome of low or high monetary value. Thus, participants acquire relations between R1-O1 (e.g., press the left key to earn 5 euro cents) and R2-O2 (e.g., press the right key to earn 20 euro cents). Next, in the Pavlovian learning phase the low and high value outcomes are associated with two unrelated other cues, thus acquiring specific relations between S1-O1 and S2-O2. Thus, R1 is related to S1 by sharing O1, while R2 is related to S2 by sharing O2. Finally, in the test phase participants are instructed to press the left or right key as quickly and accurately as possible upon presenting a response cue. Importantly, the Pavlovian cues serve as primes that are presented just before the response cues appear. Pavlovian cues are irrelevant for the RT task, but responses could still be related or unrelated to the outcome represented by the Pavlovian cues.

The rationale behind the current task pertains to the stimulus–response compatibility effect (Kornblum et al., 1990). In our case, the PIT effect can be measured by manipulating the compatibility between outcome representations of the response and the Pavlovian cue. More precisely, the Pavlovian cue associated with the high value outcome will give the response a head start, but only when this response is related to the high value outcome (cf. reward research: Capa et al., 2011; Veling & Aarts, 2010; Zedelius et al., 2012). Such response preparation is less strong when response cues are preceded by Pavlovian cues that represent a low value outcome. The differences between response times (or response accuracy) between related versus nonrelated responses to high (vs. low) value Pavlovian cues are an indicator of the strength of the specific PIT effect.

In Experiment 1 we used monetary rewards of 5 euro cents (O1) and 20 euro cents (O2) as outcomes in the instrumental learning phase (R1-O1 and R2-O2) and Pavlovian learning phase (S1-O1 and S2-O2). Experiment 2 was designed to replicate the results of Experiment 1 with higher reward value difference (i.e., 5 vs. 50 euro cents) and more trials in the test phase. We tested the hypothesis that Pavlovian cues associated with the high value outcome (e.g., 20 cents in Experiment 1 and 50 cents in Experiment 2) produce larger differences between responses related to the high versus low value than Pavlovian cues associated with the low value outcome (i.e., 5 cents in both experiments). Accordingly, the strength of the specific PIT effect should become manifest in an interaction that yields a stronger effect in the high outcome value condition compared to the low outcome value condition. The data and all analysis code are available on OSF (https://osf.io/ta4hc).

Experiment 1

Method

Participants and Design

Forty-two undergraduate students participated in the experiment. The required sample size for the 2 × 2 within-participants design experiment was determined using G*Power analysis (Faul et al., 2007), aiming to detect a medium effect size ($\eta_p^2 = .10$) with a power of .80. The power analysis indicated that at least 35 participants were needed. Considering the possible drop-out and data exclusion due to outliers, we recruited 7 more participants (20% more than required by the prior power analysis). Data from two participants were excluded from analysis: One participant reported to have failed to correctly follow instructions, and the RT data of another participant were excessively slow (> 3 *SD* from sample mean). The remaining 40 participants (8 males; mean age 23.8 (*SD* = 5.1)) participated in the experiment with a 2 (cue outcome value: low vs. high) × 2 (response outcome value: low vs. high) repeated-measures design. Participants gave written consent before starting the study, and they received a fixed amount of €2 afterward and could earn an additional payment of up to €2.50 depending on their performance during the task. The experiments are part of a larger project that was approved by the Ethics Review Board of the Faculty of Social and Behavioral Sciences, Utrecht University (approval code: FETC19-098).

Apparatus and Material

Participants sat at a desk in a 6- × 4-m soundproof cubicle, facing a computer screen (1920 × 1080 pixels), and a standard keyboard was in front of them. The experiment was run using MATLAB with Psychophysics Toolbox Version 3.0.10 (Brainard, 1997). During the entire task, the screen contained a black background and projected the instructions in white. It also presented a gray square (RGB 192 192 192, visual angle 6.60°) in the center of the screen in which cues could appear. Two colored frames (i.e., yellow, RGB 255 255 0, and blue, 0 0 255, visual angles 6.86°) surrounded the gray square and served as imperative stimuli for responses. Full-color images of a 5-cent and a 20-cent euro coin (visual angle 6.60°) served as outcomes during learning phases. We used two figures in black (i.e., a "star" and a "wave," visual angle 6.60°) as Pavlovian cues.

Procedure

Upon arrival at the laboratory, the experimenter guided participants to the cubicle where the experiment would take place. The experimenter told them that the study dealt with the question of how fast people can react to certain visual stimuli. The experimenter also informed participants that they would earn extra monetary reward during the experiment, and asked them to read the instructions very carefully. Participants signed the informed consent. The experimenter stayed in the cubicle during the entire experiment and was seated behind a divider screen to monitor the procedure of the experiment. The experiment consisted of four phases.

Demonstration phase. To familiarize participants with the speeded response task, the experiment started with a demonstration of this task. In total, participants performed 40 trials.

Instrumental learning phase. After finishing the demonstration phase. participants entered the instrumental learning phase. Participants could earn "5 cents" for pressing the left key and "20 cents" for pressing the right key (or vice versa counterbalanced across participants) in this phase. To strengthen the learning of these specific R-O relations, participants needed to speak out "5 cents" when pressing the left key and "20 cents" when pressing the right key (or vice versa).

The trial procedure depicted in Figure 1 (panel A) was as follows: A gray square would appear in the center of the screen for 1–3 s (random time interval), and then a blue or yellow frame would appear until response. Upon response, participants would speak out either "5 cents" or "20 cents" depending on the particular R-O mapping. After a correct response, either the respective 5 or 20 cents coin would show as a full-color image for 1 s. Participants first performed 20 practice trials, and although they would not yet earn real money during practice trials, they would be able to learn the correct mappings. After the practice trials, participants started with the actual task in which they could earn real money. They were presented with the image of a coin after a correct response, and the program would add the amount of money represented by the coin to their earnings. However, they could only earn coins in 50% of the trials, and in the other 50% of the trials, a blank screen would appear telling them that they would not earn money for the trial. On each trial, participants still had to speak out "5 cents" or "20 cents" regardless of the potential absence of the presentation of the coin image. Participants performed 20 real trials. At the end of the phase, participants received information about the total amount of extra earnings, which could be up to €1.25.

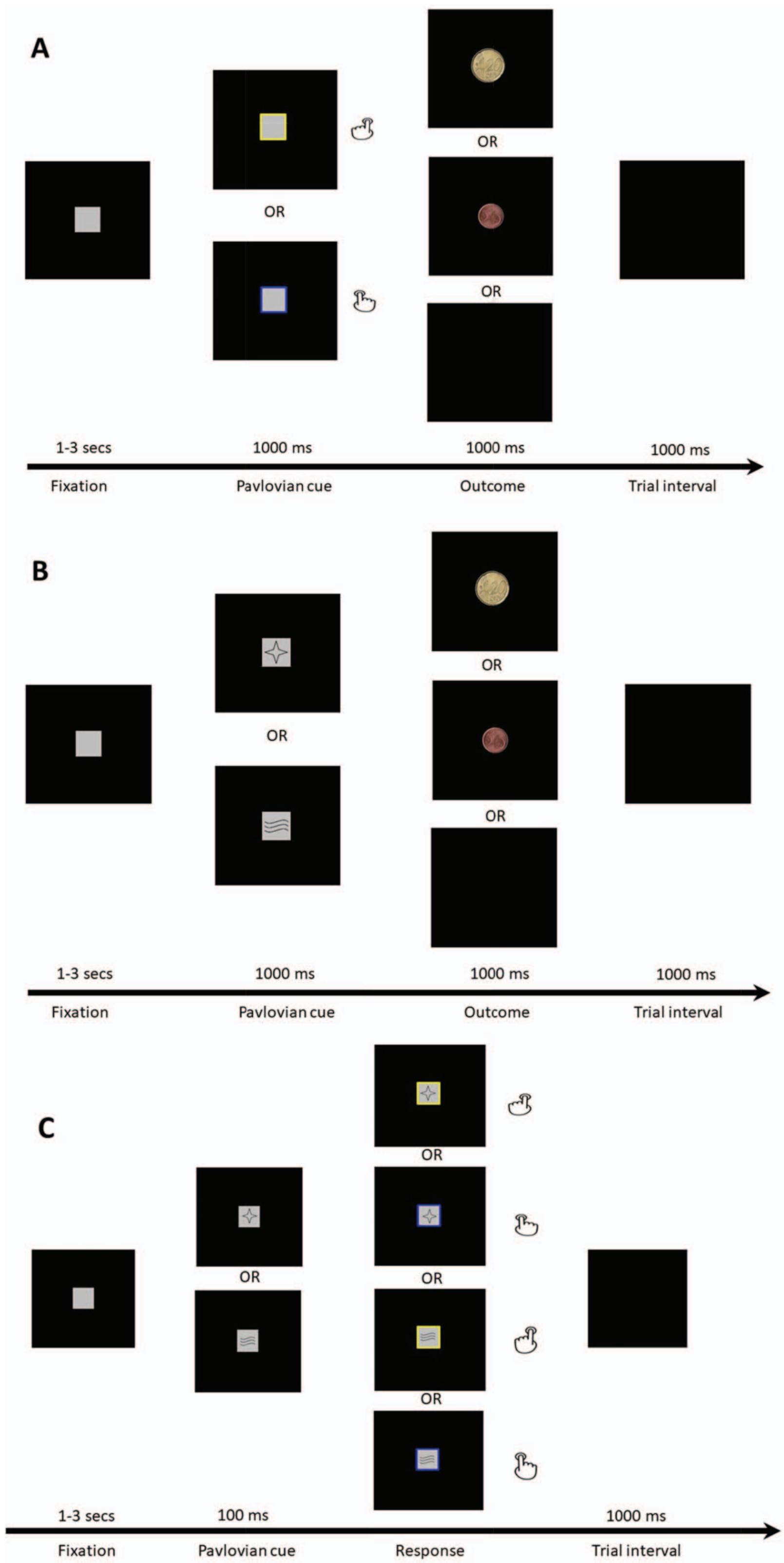
Pavlovian learning phase. In the Pavlovian learning phase, participants did not press any keys. Furthermore, no colored frames appeared around the gray square, but only the cues (a "star" or "wave") appeared inside of the gray square. Each cue would be followed by a reward (5 cents or 20 cents), and they could earn the reward by correctly verbalizing its value. They could earn "5 cents" after the presentation of a "star" and "20 cents" after the presentation of a "wave" (or vice versa counterbalanced across participants).

The trial procedure depicted in Figure 1 (panel B) was as follows: a gray square appeared for 1–3 s (random time interval), then a "star" or a "wave" would appear for 1 s. Upon presentation of these cues, participants would speak out either "5 cents" or "20 cents" depending on the particular S-O mapping. Then the respective 5 or 20 cents coin would appear as a full-color image for 1 s. Participants first performed 20 practice trials to learn the correct mappings. They would not yet earn real money during practice trials. After the practice trials, they engaged in the task where they could earn real money. Similar to the instrumental learning phase, they had to verbally express the value of a coin after a cue, and the program would add the amount of money represented by the coin to their earnings. However, they could only earn coins in 50% of the trials, and in the other 50% of the trials a blank screen would appear when they would not earn money for the trial. On each trial, participants still had to speak out "5 cents" or "20 cents" regardless of the potential absence of the presentation of the coin image. Participants performed 20 real trials. At the end of the phase, the total amount of extra earnings was presented on the screen, which could be up to €1.25.[2]

Test phase. After the Pavlovian learning phase, participants entered the test phase. In this phase, participants would not earn money anymore, and the procedure was the same as the task they

[2] We calculated the mean and the standard deviation of the error rate in the actual tasks of the instrumental and Pavlovian training phases of the two experiments. The mean response error rate and oral report error rate were very low in both experiments (e.g., around 1%), indicating that participants had learned the R-O and S-O contingency. Details can be found in the online supplemental materials in the contingency learning sections for both experiments.

Figure 1
Instrumental learning (A), Pavlovian Learning (B), Test Phase (C)



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

performed in the first phase (i.e., the demonstration phase). Additionally, participants would not need to speak out the predicted rewards anymore, but just to respond as quickly and accurately as possible to the imperative stimuli. In each trial of the task, a gray square appeared in the center of the screen that also functioned as a fixation prompt (see Figure 1, panel C). Then one of two cues (a "star" or "wave") appeared inside of the gray square after a 1–3-s randomized time interval. After a further 100 ms, a yellow or a blue frame would appear surrounding the gray square as an imperative stimulus for responding left or right, respectively (or vice versa counterbalanced across participants). Pavlovian cues remained on the screen until the response, but they were irrelevant to the task; participants only had to pay attention to the color of the frames and to respond as fast and accurately as possible by pressing the "s" key for left responses and pressing the "k" key for right responses. A blank screen appeared for 1 s after a correct response, and a red cross followed an incorrect one.

In the test phase, the cues ("star" and "wave") with "low" versus "high" outcome value (or vice versa) were combined with the responses (left and right) with "low" versus "high" outcome value. Accordingly, a value-based PIT effect can emerge when a cue of high outcome value speeds up the response of high outcome value. There were 40 trials in total.

After the test phase, to explore the influence of participants' current or general motivation for earning money, they responded to 6 items aimed to assess their need for money (e.g., "To what extent do you need money right now?") on a 7-point Likert scale. These data did not turn out to be informative and will not be discussed any further. At the end of the experiment, participants received their payout in cash, depending on their performance.

Data Preparation and Analyses

First, RT data of the correct responses in the test phase were trimmed for outliers (Lachaud & Renaud, 2011). RTs slower or faster than 3 *SD* of the mean of the participant were removed from analyses (3.4% of the RT data). Since the RT data were not normally distributed, we performed a reciprocal transformation (i.e., 1/x) to normalize the distributions (for details, see the online supplemental materials), and we used the transformed RTs for further tests. Considering that the conventional 2 × 2 repeated-measures ANOVA may not capture the predicted pattern for RT, we performed a planned contrast using an *F* test with partial eta squared (η^2_p) as effect size, which is reported with a 90% CI (Furr & Rosenthal, 2003; Rosenthal & Rosnow, 1985).

To integrate, we predicted a value-based cue-driven effect: Based on the notion of the compatibility effect, in the high (20 cents) value cue outcome trials, participants should respond faster on high (20 cents) value cue responses compared to low (5 cents) value cue responses. Furthermore, in the low (5 cents) value cue outcome trials, participants should respond faster on low (5 cents) value cue responses compared to low (20 cents) value cue responses. More importantly, the former effect should be more pronounced than the latter. Thus, we defined each cell of the contrast 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. We performed the identical data transformation for accuracy since it was not normally distributed either (see the online supplemental materials). We also conducted a planned contrast for accuracy with a minor change of the coding: +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. This follows from the compatibility effect, indicating that participants should respond more accurately when the Pavlovian cue shares the same outcome representation with the response, and this effect should be more pronounced in the high value condition.

Results

Reaction Times in the Test Phase

The pattern of RTs is presented in Figure 2.[3] The planned contrast was significant ($F(1, 39) = 6.49$, $p = .015$, $\eta^2_p = .14$ [0.017; 0.316]). This indicates that participants responded faster when the cue and the response predicted the same outcome compared to when the cue and the response predicted different outcomes, and this effect was more pronounced in 20 cents value cue condition. However, looking more closely at the pattern in Figure 2, RTs in the low-value cue condition do not seem to be in line with this interpretation, so these findings, although significant, do not fully conform to our predictions.

Accuracy in the Test Phase

The planned contrast did not yield the predicted pattern for accuracy, $F(1, 39) = 0.03$, $p = .868$. Figure 3 presents the means of the accuracy scores in each cell of the design.

Discussion

Although the significance of the planned contrast test with a medium effect size ($\eta^2_p = .14$) provides initial evidence that the strength of the specific PIT effect is value based, the pattern of RTs was not fully in line with our predictions. RTs in the low-value cue condition were expected to be lower for the 5 cents responses compared to the 20 cents responses, but this pattern was not observed. Additionally, the specific PIT effect in the high value condition was only observed on RTs and not on accuracy. So before we draw any conclusions about the possible implications of these findings for research on PIT in human subjects, we deemed it important to provide an independent replication of these effects. To increase the power and sensitivity of the test, we made three modifications. We increased (1) the sample size, (2) the number of trials in the test phase, and (3) the monetary units of the high value reward (50 cents instead of 20 cents).

Experiment 2

Method

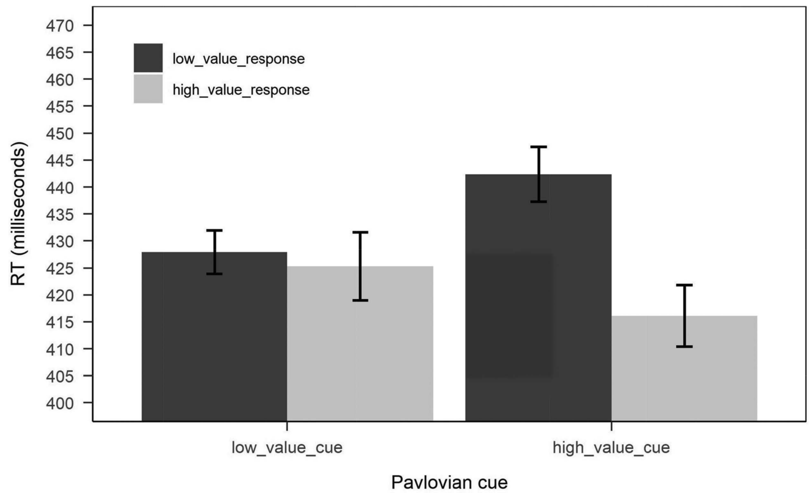
Participants and Design

Compared to Experiment 1, we increased the sample size with 15 extra participants. Thus, we recruited 57 undergraduate students for Experiment 2. Data from one participant were excluded from

[3] For clarifying the predicted pattern, figures of RTs and accuracy in both experiments were presented with untransformed data.

Figure 2

Reaction Times in the Test Phase of Experiment 1 as a Function of Cue Outcome Value and Response Outcome Value



Note. Error bars represent 1 standard error of the mean.

analysis because the RT data were excessively slow (> 3 *SD* from sample mean). The remaining 56 participants (29 males; mean age 24.6 (*SD* = 4.8)) participated in the experiment with a 2 (cue outcome value: low vs. high) × 2 (response outcome value: low vs. high) repeated-measures design. Participants gave written consent before starting the study, and they received a fixed amount of €1 afterward and could earn an additional payment of up to €5.50 depending on their performance during the task.

Apparatus and Material

Apparatus and material were the same as in Experiment 1 except for the image of a 20-cent coin, which was replaced by a 50-cent coin image.

Procedure

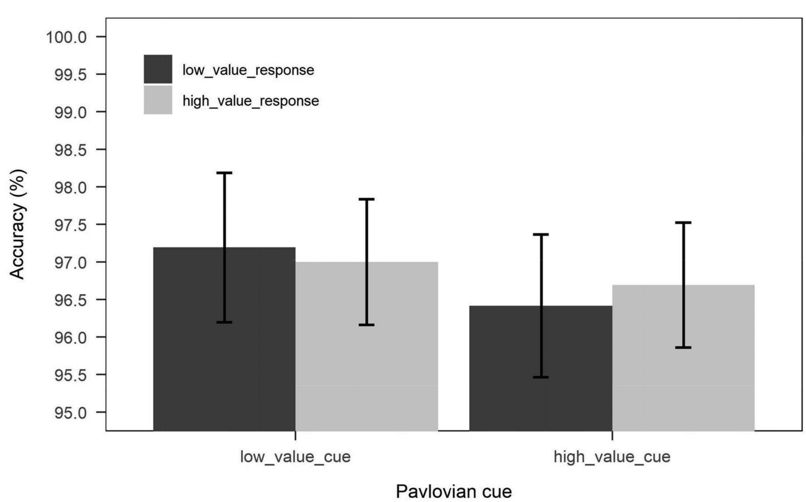
The procedure was similar to Experiment 1. The demonstration phase was the same as in Experiment 1, with 40 trials in total. The instrumental and Pavlovian learning phase were the same except that the "20 cents" was replaced with "50 cents" so that the additional earnings went up to €2.75 after each learning phase. The test phase was the same as in Experiment 1 but was extended to four blocks of 40 trials so that participants performed 160 trials in total.

Data Preparation

In line with the first experiment, RT data of the correct responses in the test phase were trimmed for outliers. RTs slower or

Figure 3

Accuracy in the Test Phase of Experiment 1 as a Function of Cue Outcome Value and Response Outcome Value



Note. Error bars represent 1 standard error of the mean.

faster than 3 *SD* of the mean of the participant were removed from analyses (2.9% of the RT data). We then performed a reciprocal transformation (i.e., 1/x) since the RTs were not normally distributed. (see the online supplemental materials), and we used the transformed RTs for further tests. Similar to Experiment 1, we performed a planned contrast using an *F* test, and the effect size was also reported as partial eta squared (η^2_p) with a 90% CI to test the predicted pattern. The coding for the contrast was defined as follows: −1 for the 5 cents response/5 cents cue cell, +2 for the 50 cents response/5 cents cue cell, +2 for the 5 cents response/50 cents cue cell, and −3 for the 50 cents response/50 cents cue cell. As for accuracy, we computed a reciprocal transformation of the accuracy score, because it was not normally distributed either (see the online supplemental materials). We also performed the identical planned contrast test for accuracy, with a minor change of the coding, as we did in Experiment 1.

Results

Reaction Times in the Test Phase

The pattern of RTs is presented in Figure 4. The planned contrast was significant and the pattern of RTs in line with the predicted pattern: Participants responded faster when the cue and the response shared the same outcome representation compared to when the cue and the response predicted different outcomes, and this effect was more pronounced in the high (50 cents) value outcome cue condition ($F(1, 55) = 4.40$, $p = .041$, $\eta^2_p = .07$ [0.002; 0.205]).

Accuracy in the Test Phase

The pattern of accuracies is presented in Figure 5. The planned contrast was significant, $F(1, 55) = 7.36$, $p = .009$, $\eta^2_p = .12$ [0.018; 0.260], and the accuracy measure yielded the same pattern as was observed in the RT analysis. Participants had higher accuracy scores when the cue and the response predicted the same outcome compared to when the cue and the response predicted the different outcomes, and this effect was more pronounced in the high (50 cents) outcome value cue condition.

Discussion

Findings of the second experiment corroborated the results of Experiment 1. The predicted pattern was now fully reflected in the observed RTs pattern. Namely, responses were faster when the cue and the response shared the same outcome representation, compared to when the cue and the response led to different outcomes. In line with a value-based account, this effect was more pronounced in the high value condition. Experiment 2 yielded an effect size on RTs ($\eta^2_p = .07$) that seems smaller than Experiment 1($\eta^2_p = .14$). However, Experiment 2 did yield an effect on accuracy with a medium effect size ($\eta^2_p = .12$) as well. Overall, the effects were strong enough to treat them as true positives. Thus, responses to cues were particularly faster and more accurate when the cue and response shared a high value outcome, demonstrating a valued-based specific PIT effect on both RTs and accuracy.

General Discussion

A major theme in the study on environmental control of human behavior concerns the question of whether such behavior is mediated by the representation of a desired outcome or by a direct cue-behavior association (Mahlberg et al., 2019; Marien et al., 2015; Weingarten et al., 2016). To address this issue, the present study examined a novel paradigm to test specific PIT effects in a cue-based forced choice speeded task including multiple responses that are instrumental in obtaining low versus high value outcomes. Results of two experiments showed that cues associated with outcomes triggered responses that were instrumental in obtaining the outcomes, as was demonstrated by faster and more accurate responses upon exposure to these cues. Importantly, these effects were more pronounced when the value of outcome was high: Pavlovian cues associated with high outcomes triggered responses of high (vs. low) value outcomes, while the difference between the two types of responses was much weaker for Pavlovian cues associated with low outcomes. These latter findings speak to a value-based specific PIT effect, showing a stronger instance of goal-directed cue-based behavior when action and cue share outcomes that are important.

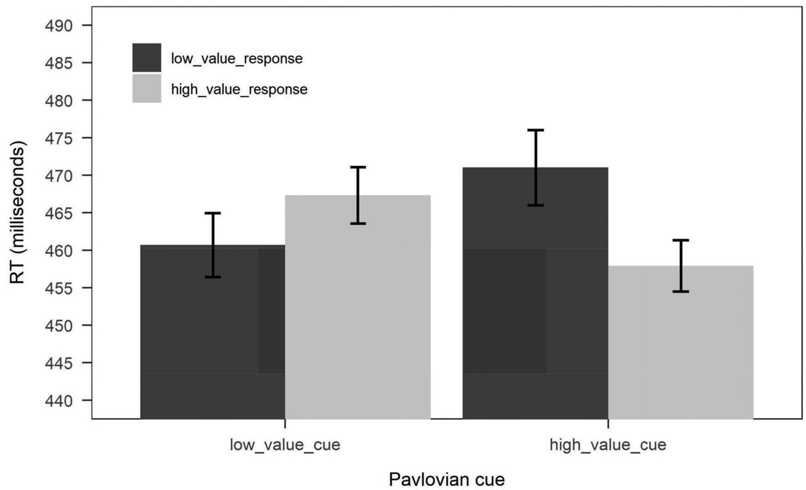
The present finding that the specific PIT is conditional on the value of the outcome is noteworthy, especially in the context of previous similar research on PIT in human behavior (Jeffs & Duka, 2017; Watson et al., 2016). For instance, Watson et al. (2016) found that subjects choose the response belonging to the high outcome cue more often than the response of the low outcome cue. However, high outcome cues evoked slower responses compared to low outcome cues (Watson et al., 2016, Experiment 2), indicating a reversed specific PIT effect. In another study (Jeffs & Duka, 2017), participants preferred low outcome responses to cues that were linked to low outcome and high outcome responses that were linked to high outcome. Although these effects suggest that the value of the outcome did not matter, this research implemented a free-choice setting, which might have allowed participants to act strategically in the task at hand. The present studies aimed to rule out this issue by using a PIT task where responses are forced and primed by Pavlovian cues.

Our findings are also relevant for the current debate on whether PIT is goal-directed or habitual (Mahlberg et al., 2019). Based on animal behavior research, past studies used devaluation procedures to investigate whether reward value matters in the specific PIT effect (Eder, & Dignath, 2016a; Hogarth & Chase, 2011; Seabrooke et al., 2017; Watson et al., 2014). According to devaluation studies, the specific PIT effect represents goal-directed behavior if the effect vanishes when the outcome no longer has value. However, existing empirical evidence is mixed. Specifically, some studies fail to show the devaluation effect, which is taken as evidence for a habit process that operates without any goal representations involved. Although habits play a major role in daily life (Marien et al., 2019), some of these studies probably implemented devaluation procedures that were too weak or failed to target the goal that was driving behavior (De Houwer et al., 2018; Eder & Dignath, 2016b), leading to the conclusion that the behavior was not goal-directed.

Even though the present studies take a different angle in using direct manipulation of reward value in the acquisition phase instead of a devaluation procedure, our results do seem to support a goal-directed account. It is important to note that the current study implemented a complete extinction procedure in the test phase to avoid a learning effect of the stimulus–response relationships

Figure 4

Reaction Times in the Test Phase of Experiment 2 as a Function of Cue Outcome Value and Response Outcome Value



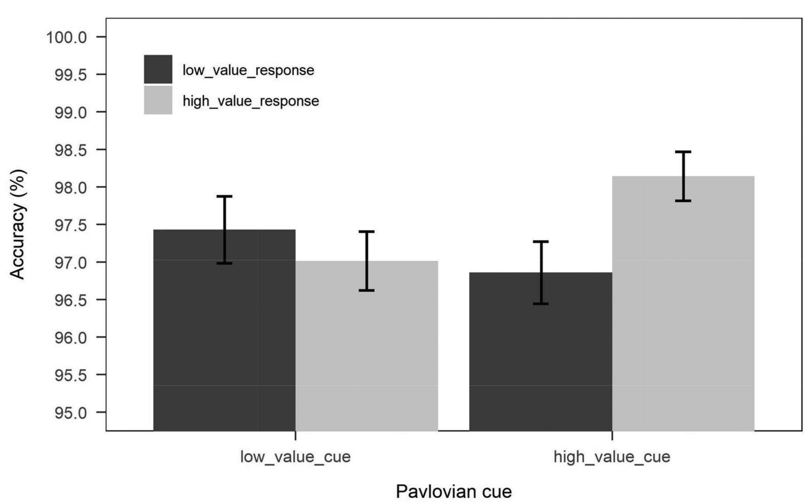
Note. Error bars represent 1 standard error of the mean.

emerging during the transfer test (Colagiuri & Lovibond, 2015; Lovibond et al., 2015). In other words, there were no valuable outcomes to be attained during the test phase. The goal-directed property (i.e., sensitive to the value of the outcome) found in the current studies can thus be explained by the residual potency of the triggered outcome representation to still activate the associated reward value under extinction (Bezzina et al., 2016). This fits well with previous research suggesting that representations of rewards can prime instrumental action directly, and can be facilitated for sustained periods of time (Zedelius et al., 2014).

It is important to stress that in the current studies, the PIT effect was measured in a stimulus–response compatibility context. Specifically, when the outcome representation of the Pavlovian cue and the instrumental responses were compatible, participants' responses were faster and more accurate than on incompatible trials. Whereas such stimulus–response compatibility effects are thought to ensue from response facilitation and/or interference (Hübner & Többel, 2019; Simon & Acosta, 1982), it is not clear from our findings which of these two processes are responsible for the value-based PIT effect. To more specifically address this issue, one needs to include a baseline condition with a neutral cue. Therefore, it might be an interesting avenue for future research to include such a baseline cue to disentangle response facilitation from interference in PIT effects.

Figure 5

Accuracy in the Test Phase of Experiment 2 as a Function of Cue Outcome Value and Response Outcome Value



Note. Error bars represent 1 standard error of the mean.

Finally, the present method might be added as a valuable instrument to the PIT toolbox for examining cue-based control of goal-directed human behavior. The imperative nature of the task concerning the facilitation of responses to outcome-related cues makes it less prone to strategic task behavior or other forms of demand characteristics. However, we wish to stress that the value of such a tool hinges on the exact nature and question that one wants to address with PIT. The original objective for using PIT was to demonstrate that animal behavior does not only build on S-R links but also on representations of desired outcomes based on the knowledge of outcome behavior contingencies (Crombag, Galarce, & Holland, 2008; Crombag, Sutton, et al., 2008; Lederle et al., 2011; Lex & Hauber, 2008). However, investigating the role of outcome representations in animal behavior is different from human research. First, animal behavior research heavily relies on primary needs (such as hunger or thirst). Second, response-outcome contingencies are learned by trial and error. Third, PIT is tested in a setting that allows test animals to respond to specific cues. The present studies divert from such a basic learning process and address actions in response to high (vs. low) monetary outcome cues that are more socially important and do not directly rely on primary needs. Perhaps, then, it is the test stage as part of our novel method that offers an important window to conditions that render human behavior directed toward more meaningful goals in social contexts (Aarts et al., 2004; McCulloch et al., 2011).

To conclude, the current study tested a novel PIT task to address the environmental control of human goal pursuit. The results of the two experiments both supported a goal-directed account for responses to cues: The PIT effect was specific and sensitive to the value of the outcome. We hope and believe that this novel paradigm provides opportunities to gain more insight into the role of value-based outcome representations in cue-driven human behavior.

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