Revisiting Automatic Goal Pursuit:
Exploring the Value of Goals in Cue-Based Behavior

Kaiyang Qin | 覃恺洋

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Revisiting Automatic Goal Pursuit: Exploring the Value of Goals in Cue-Based Behavior

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door

Kaiyang Qin
geboren op 27 November 1991
te Hubei, China

Promotors:

Prof. dr. H. Aarts

Dr. R. Custers

Copromotor:

Dr. H. Marien

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Chapter 1:

Introduction and overview

Human beings are reward-seeking creatures. Satisfying needs and finding pleasure are essential for well-being and survival. In a stable world, rewards often result from the same actions in the same situations. In psychology, such a fixed status of human behavior is often regarded as habitual, with rewards reinforcing associations between actions and situations due to learning and repetition. For instance, if a motor behavior (e.g., pressing a lever) is repeatedly executed and reinforced in response to the same stimulus (e.g., a drop of sweet water), the stimulus may, at some point, directly cue the behavior. As such, rewards initially play an important role in forming habits through which, eventually, the environment determines human behavior (see Wood & Rünger, 2016).

Habit accounts have dominated the understanding of environmental control of behavior for many years (see Marien et al., 2019). Habits have been considered to be the driving force underlying behavior and can be conceptualized at different levels of meaning and operation, such as switching on a light when sitting at the table, teeth-brushing in the bathroom, eating popcorn in the cinema, and traveling to work on Monday. Across those levels, though, behavior is assumed to be a direct result of perceived cues in the environment. However, studies addressing the role of cognition and motivation in behavior suggest that environmental cues can also trigger and encourage behavior indirectly. That is, cues may first activate a representation of the action outcome, which then, in turn, leads to the execution of the behavior. This indirect effect is thought to originate from the human (or the brain's) capacity to predict and represent the outcomes of our own actions and the rewards they produce (Frith et al., 2000; Gilbert & Wilson, 2007; Miller et al., 1960; Powers, 1973; Suddendorf & Corballis, 2007; Tolman, 1939). According to this view, the environment can evoke specific goals that influence the execution of actions and promote the attainment of the anticipated outcome. Thus, switching on a light might result from the anticipation of reading a book or traveling to work may serve the goal of meeting colleagues.

Understanding and appreciating cue-based behavior as being driven by goals rather than mere habits is not trivial. First, it paints the picture that the human mind is more frequently involved in causing our behavior in recurring environments than surveys and experiences suggest. That is, we may report executing our actions automatically by the force of habit without much thinking and attentional effort, while in fact, they are directed by goals that build on (albeit implicit or explicit) cognitive processes to navigate the complex world. Secondly, interventions to change behavior build on different approaches when the target behavior is habitual or goal-directed. Habit interventions target the environment in which habits occur (e.g., Wood & Neal, 2016), while goal interventions focus on the mental states that underlie the initiation and persistence of goal-directed behavior (e.g., Michie & Johnston, 2012). Thus, when one wants people to get out of their car, one could change the built environment in which car use usually occurs or change their mind by, e.g., decreasing the perceived value and feasibility of car use in the situation at hand.

The idea that cues in the environment can serve as a basic source for directing human goal-directed behavior appears to be well-accepted by most contemporary researchers and theorists from different research areas, such as social, health, and consumer psychology (Aarts, 2007; Baumgartner & Pieters, 2008; Gęsiarz & Crockett, 2015). The evidence of cue-based goal-directed behavior builds on different lines of research showing how goals of personal and social importance can come under the control of the environment, even outside of awareness (Custers & Aarts, 2010). Although the question of whether goal pursuit can occur fully outside of awareness at several levels of behavior is still a matter of debate (Custers & Aarts, 2010; Laran et al., 2016; Laran et al., 2018), the understanding and examination of the direct control of goal-directed behavior by the environment are plagued by the absence of clear methods or tests (Marien et al., 2019; Watson et al., 2018).

In the present thesis, I aim to address this important issue. Specifically, I will examine how the environment triggers socially meaningful behaviors and operate at a relatively high cognitive level of abstraction (e.g., earning money, acting prosocial). To this end, I build on research on the distinction between habit and goal-directed behavior in animal research (Corbit et al., 2007; Estes, 1943; Holland, 2004; Holland & Gallagher, 2003) and draw on a paradigm that can distinguish between two components of behavior: Pavlovian-to-Instrumental Transfer (PIT). In PIT, instrumental learning (e.g., pressing a key yields food) is separated from Pavlovian learning (e.g., a stimulus predicts food) in two distinct learning phases. As a result, if the stimulus is found to trigger the instrumental behavior in a later test phase, the effect cannot be explained by a stimulus-response association reinforcement, as the two have never been paired in the learning phase. Instead, the effect must be caused by Pavlovian-to-instrumental transfer: The stimulus triggers the representation of the associated outcome, which in turn triggers the associated behavior. While this paradigm has been used to establish goal-directed behavior in animals, it has the potential to examine cue-based goal-directed behaviors in humans at several levels of meaning and operation -- behaviors that previously have been categorized as habitual (Wood & Rünger, 2016).

In the next section, I will discuss in more detail the habitual and goal-directed account of cue-based behavior and how the two processes relate to each other in terms of obtaining socially meaningful outcomes. Subsequently, I will focus on one important line of research that provides initial evidence for cue-based goal-directed behavior, especially for socially meaningful goals: research on automatic goal pursuit. After that, I will introduce PIT as a potential paradigm and discuss how it can be used to solve these issues. These claims will be backed up by evidence resulting from the empirical chapters of this dissertation, demonstrating that PIT can be a way to test cue-based goal-directed behavior. I will end this introductory chapter with a general discussion, some final conclusions, and implications for future research.

Cue-based behavior: Habitual or Goal-directed?

People perform all sorts of reward-seeking actions daily. Such actions are likely to be repeated in the same environment once rewarded in that environment (Skinner, 1953). This way, actions become associated with environmental cues. Whenever the cues are perceived, individuals perform the well-learned behavior automatically (Wood & Rünger, 2016). Behavior resulting from this process is often regarded as habitual. According to an experience-sampling diary study, almost 43% of people's behavior recorded in their diaries was repeated in the same environment (Wood et al., 2002). For example, whenever individuals enter the kitchen after getting up in the morning, they may habitually open the fridge to get something to eat. This behavior could be explained by the sight of the fridge triggering the behavior of opening it, which is then reinforced by the reward (food), and has been in the past.

Alternatively, it is possible that the fridge brings to mind or activates the representation of the desired outcome (eating food), which then facilitates the action of opening the fridge. Indeed, it may very well be that individuals have also learned the association of the desirable outcome with the environmental cue (i.e., the fridge) and the behavior (i.e., opening the fridge). According to this perspective, the desirable outcome does not merely act as a reinforcer but becomes part of the associative structure that governs behavior. That is, the outcome representation is assumed to be activated by the cue, motivating individuals to perform the behavior (e.g., opening the fridge) to attain the desirable outcome. This cuing behavior process can be termed goal-directed because it is guided by individuals' motivation to achieve the desirable outcome (Dickinson & Balleine, 1994; 1995).

Following these two competing accounts of cue-based behavior, there is a current debate about whether socially meaningful behavior that operates at a high level of conceptualization and cognitive abstraction is driven by habits or goals (De Houwer et al., 2018; Kruglanski & Szumowska, 2020; Marien et al., 2019). This debate is guided by research published in the psychological literature. For example, Neal and colleagues (2011, 2012) studied individuals in the context of public places (sports stadiums, cinema) to infer whether their behavior was habitual or goal-directed. In one study examining snacking in the cinema, Neal and colleagues (2011) exploited the devaluation effect (i.e., making food less attractive). They found that participants who reported being frequent popcorn eaters in cinemas ate as much stale as fresh popcorn but only when in the cinema context. These findings suggest that popcorn consumption was a habit and no longer controlled by the goal of eating it.

Although promising, the self-reported frequency measure and correlational nature of the study do not rule out that other goals than popcorn eating controlled the behavior (e.g., having a good time and being with friends). Human habits can often look like direct responses to environments while, in fact, they are conditional on a person's goals hidden in the context at hand (Custers & Aarts, 2010; Marien et al., 2018). In an important contribution to this debate, De Houwer and colleagues maintained and showed that when outcome devaluation is directed at a lower level action-goal (e.g., eating crisps in response to blue light) and not at the task goal (e.g., earning points for doing this fast), one may falsely conclude that the behavior is habitual because the behavioral response is actually under the control of the general task goal (De Houwer et al., 2018).

In line with the above-mentioned issue, Aarts & Dijksterhuis (2000a) proposed that habits are knowledge structures in which the context, goals, and actions are lumped together, ready to be activated and enacted upon in the context at hand. To test this idea, they asked participants to identify a travel mode (e.g., bicycle) presented on the screen after being given a goal in a travel context (e.g., going to get groceries). Furthermore, participants were exposed to travel-location cues (e.g., market) or not just before responding to the travel mode. Results showed that habitual (vs. nonhabitual) bicycle users responded faster to identify a bicycle after the travel goal was given, while the location cue did not matter. In other words, the cue did not directly trigger the transport mode action. It was the goal that did so. These findings have been replicated in studies examining different response setups as well as different behaviors (e.g., Aarts & Dijksterhuis, 2000b; Danner et al., 2007; Danner et al., 2008; de Vries et al., 2011; Légal et al., 2016; Sheeran et al., 2005).

In a recent summary of these findings, Marien et al. (2019) argued that cue-based behavior is more likely to be habitually driven when executed on a very low level of operation (sensorimotor level). However, in studies that consider habits as underlying causes of societal problems, such as the human impact on climate change and health problems, cue-based behavior is mediated by goals. Most of these studies conceptualize and measure habits at high levels of operation and abstraction (e.g., eating unhealthy food or taking the car). These operations or abstractions are likely goal-oriented and rely on anticipation of action outcomes and mental processes involved in selecting and persisting in action in the face of obstacles to reach the desired outcome. An important area of research that indeed considers the mental representation of action outcomes to be crucial in cue-based goal-directed behavior is research on automatic goal pursuit, which I will discuss in the next section.

Automatic Goal Pursuit

One of the research lines relevant to the idea that environmental cues can trigger goal-directed behavior is automatic goal pursuit. In this area, researchers capitalize on the notion that actions are mentally represented in terms of their effects, as has been studied in ideo-motor learning research (Greenwald, 1970; Shin et al., 2010; Sun et al., 2020). Mental representations of desirable action outcomes can be considered as goals that mediate the environment-behavior link. In a typical study on automatic goal pursuit, participants are presented with a word (e.g., cooperation) or a picture (e.g., a running athlete) that is associated with a specific goal (help or win) and are then given the opportunity to reach the associated goal (e.g., in a task where they can help someone or solve puzzles to win). By using several variations of this procedure, researchers have found that a variety of goals, such as achieving, helping, and even making money, can be triggered by environmental cues and motivate people's actions in line with these goals (for reviews, see, e.g., Chen et al., 2021; Dai et al., 2023; Weingarten et al., 2016).

Such automatic goal pursuit effects can be explained by a stepwise learning process. First, exposure to cues in the environment alters the accessibility of cue-related mental content and awareness of the situation, which then produces downstream effects on judgment, behavior, or motivation (Loersch & Payne, 2011). Furthermore, with more repetition and practice, the role of the conscious mind dwindles, making room for shortcuts and a more automatic process, in the sense that cues guide goal-directed behavior without a consciously formed intention and much thought (Custers & Aarts, 2010).

For example, in a set of studies on cue-based goal-directed behavior in the domain of test performance (Hassin et al., 2009), participants were asked to complete a word-search puzzle that included either words related to achievement motivation (such as "win", "achieve" and "succeed") or words unrelated to achievement (such as "window", "carpet" and "hat"). Next, they took the Wisconsin Card Sorting Test (Study 1) or the Iowa Gambling Task (Study 2), which both measure people's ability to adapt to changing circumstances (e.g., Bechara et al., 1997; Heaton et al., 1993). The results of both studies showed that those who were exposed to achievement motivation words outperformed those in the control condition. More importantly, participants were unaware of the connection between the words in the puzzle and the subsequent task. Similar observations have been reported in the domain of school tests (e.g., Engeser et al., 2016), sports (e.g., Friedman & Elliot, 2008), and organizational behavior (Stajkovic et al., 2019). These findings suggest that environmental cues can automatically activate goals and influence behavior, even without conscious intention or awareness.

Although such findings speak to the occurrence of cue-based goal-directed behavior, it is important to note that studies on automatic goal pursuit have been suggested to suffer from replication issues, just like in other major areas of psychological science (Maiers, 2022; Maxwell et al., 2015; Tackett et al., 2019). Reasons for difficulties in replications vary from publication bias, file drawer problems, and sampling issues to questionable research practices. Despite these important issues surrounding the replication of studies in psychological science, a recent meta-analysis on word-activation effects on behavior across different psychology domains suggests that, overall, automatic goal pursuit effects are small to moderate. Moreover, they hold up, particularly for goals with high value in the eyes of the automatic goal pursuers (Dai et al., 2023; Weingarten et al., 2016).

The role of goal value in automatic goal pursuit has been mainly studied with word stimuli. As such, these studies are an important step in linking cue-based goal-directed behavior to motivational processes that render behavior more effortful when facing difficulties in attaining the goal. Building on this idea, others have examined the direct effects of monetary rewards on performance and effort. Typically, in these studies, participants are exposed to pictures of low or high-value coins they could earn when performing well on an effortful task (working memory or key-tapping task). The coins are fully visible or flashed so briefly that they are almost impossible to consciously perceive (e.g., Bijleveld et al., 2012a; Pessiglione et al., 2007; Zedelius et al., 2013; 2014). The overall findings show that when effort requirements are high, participants respond more vigorously to high-value rewards than low-value rewards, and this effect on effort investment is independent of conscious awareness of the coins (Bijleveld et al., 2012a, Experiment 1).

In offering an account of monetary reward driven goal pursuit effects, Bijleveld et al. (2012b) suggested that the human brain can process reward information outside of awareness based on rudimentary brain functions, which only require little perceptual input about the reward. More importantly, such initial reward processing is enough to boost efforts and facilitate performance without the involvement of consciousness. Once the information is fully processed and accompanied by awareness, a more deliberate process takes over, allowing people to make strategic decisions (e.g., make speed-accuracy tradeoffs). Such a two-stage reward processing model thus explains why cue-based goal-directed behavior occurs even when people are unconsciously exposed to reward cues.

The overall evidence for the effect of cue exposure (albeit words or pictures of coins) on goal pursuit speaks to the existence of cue-based goal-directed behavior. However, it has been pointed out, though, that while these studies hint at the involvement of goal representations, previous work on automatic goal pursuit does not properly distinguish between behavior that is activated directly by the cues and behavior that is mediated by representations of desired outcomes (Custers & Aarts, 2010; Marien et al., 2019; Watson et al., 2018). That is, the cues used in these studies are usually associated with both the goal and the instrumental actions causing them in daily life. Therefore, it is impossible to distinguish between the direct and indirect effects of cues on behavior.

In what follows, I will discuss in more detail the paradigm that might be suitable to address and test this question: the Pavlovian-to-Instrumental Transfer paradigm (PIT; Cartoni et al., 2016; Mahlberg et al., 2021). As noted earlier, this paradigm separates two types of learning: instrumental (action-outcome) learning and Pavlovian (cue-outcome) learning. This way, outcomes are associated with instrumental actions and cues, while there is no acquired association between the action and the cue as a result of direct pairing or learning. Any effect of cue exposure on the action then is suggested to run via the outcome representation, that is, the goal of the action.

Automatic goal pursuit in light of the PIT paradigm

The PIT paradigm was originally developed to demonstrate that animal behavior is not solely based on stimulus-response links but also governed by the representation of desired outcomes derived from knowledge of action-outcome contingencies. (Corbit & Balleine, 2007; Crombag, Galarce, et al., 2008; Crombag, Sutton, et al., 2008; Lederle et al., 2011). More recently, human studies have also employed this paradigm and found that, like rodents, human participants are more likely to select a specific action (e.g., pressing a left or right key) when a Pavlovian cue predicts the rewarding outcome of that action than when a cue is not associated with the outcome. This demonstrates that cues can indirectly facilitate human actions through representations of desired outcomes (Lovibond & Colagiuri, 2013; Lovibond et al., 2015). To investigate whether cues only trigger those responses that are distinctly directed at particular outcomes, researchers use paradigms that test for outcome-specific PIT effects and found that participants' responses are only facilitated when the cue and the response are associated with the same outcome (e.g., Seabrooke et al., 2019). Summarized from the existing specific PIT studies, recent reviews conclude that the specific PIT effect is value-sensitive (Mahlberg et al., 2021, Watson & de Wit, 2018), meaning that the strength of the PIT effect increases with the value of the specific outcome. Hence, the specific PIT effect has the potential to investigate the goal-directed nature of cue-driven behaviors in humans.

In contrast to the myriad of different outcomes humans pursue in their lives, most PIT studies only cover the outcomes relevant to basic needs, such as food and drinks (e.g., Eder & Dignath, 2016b). However, some studies looked at more socially meaningful outcomes in PIT (e.g., Lehner et al., 2017; Nadler et al., 2011; Vogel et al., 2018), speaking to cue-based goal-directed behavior at a high-level goal pursuit. For example, in one study, researchers used monetary, food, and social rewards (e.g., thumbs up from others). They found that such different rewards are equally effective in PIT if their subjective values are matched (Lehner et al., 2017). It should be stressed, though, that this study used a handgrip measure as the PIT test, and the specific PIT was operationalized by the left or right-hand squeezing when exposed to two cues, respectively. Hence, the left or right-handedness of participants might have confounded the observed results when they were required to squeeze a particular hand in response to two different cues. Due to this potential methodological issue, this study did not yield a clear and comparable specific PIT effect for each different reward (e.g., food vs. social reward).

Additionally, in some PIT studies, participants engage in instrumental learning, where they are instructed to press keys to earn points. The points, then, can be exchanged for different rewards, such as candy bars or crisps (e.g., Seabrooke et al., 2019). In so doing, the points earned during the experiment are not rewarding outcomes per se but serve more like a tool to achieve the ultimate desired goal (e.g., earning snacks). This resonates well with the notion that goal-directed behavior is hierarchically organized and guided by the implications in the context at hand (Carver & Scheier, 1981; Gallistel, 1985; Kruglanski et al., 2002; Vallacher & Wegner, 1987). From this perspective, the PIT paradigm allows researchers to examine cue-based goal-directed behavior by manipulating the context or the level at which actions and outcomes are represented. This paves the way for investigating automatic goal pursuit through the lens of PIT.

In short, the PIT paradigm can be a valuable tool to investigate the question of whether and how the environment can evoke behavior that results from socially meaningful goals, as is proposed in the automatic goal pursuit literature. In the next section, I will discuss this issue further, with a special focus on assessing PIT effects in the context of goal pursuit and introducing goals that represent desired outcomes guiding actions at a relatively high level of operation.

PIT and testing automatic goal pursuit: A forced-choice paradigm

While research on PIT in animals mainly looks at response frequency as a measure of behavior (Cartoni et al., 2016), PIT research with human subjects commonly employs choice tasks in which participants are asked to select an action option in response to a cue freely. Whereas choice measures represent people's explicit preferences of options, choice measures are not without problems if one wishes to address cue-based goal-directed behavior from the perspective of automatic goal pursuit. First, choice measures instigate strategic processes that may misrepresent the automatic nature of cue-based initiation of goal-directed behavior. For example, participants may strategically press a specific key in response to a specific cue to please the experimenter, thus rendering choice measure prone to demand characteristics. Furthermore, participants may form a strategy during the PIT task that may overrule the PIT effect ("I press the left button every time I see the blue cue, and I push the right key when seeing the yellow cue"). In both cases, it is less clear whether the presence (or absence) of a PIT effect stems from a motivational goal-directed process (or habit process) or from the above-mentioned strategic process. Accordingly, if the PIT effect needs to represent an automatic goal pursuit process, one should try to rule out strategic processes in the PIT task.

One way to deal with this is to rely on initiation measures of behavioral responses to cues in humans, such as often assessed in stimulus-responses compatibility tasks. In these tasks, participants must make a forced choice while being exposed to stimuli (Kornblum et al., 1990). The typical effect is that a stimulus facilitates the speed of a required response when that response is associated with the stimulus. However, a stimulus interferes with a required response when the stimulus evokes the opposite action. An example is the Simon effect (e.g., Simon & Acosta, 1982), in which participants respond with left or right key presses to, for instance, the high and low tones and show (a) facilitation effects (faster responses and fewer errors) if the tones are presented at the location that is similar to the required response (e.g., pressing left when the tone is presented left) but (b) interference effects (slower responses and more errors) if the tones are presented at the location that is opposite to the required response (e.g., pressing left when the tone is presented right).

The compatibility effect offers a vital building block for testing the PIT effect in a forced-choice task (Qin et al., 2021). In such a test, participants must respond with two different outcome-associated actions acquired in the Instrumental learning stage upon exposure to two specific cues used in the Pavlovian learning stage to train them to link these cues to one of the two outcomes. If a PIT effect occurs, a response should be facilitated by a cue when the cue is linked to a specific outcome that has been learned to produce this outcome. The specific PIT effect of high and low-value outcome cues thus can be measured by comparing reaction times and accuracies for the two different cues. If the facilitation effect of the high-value cue is stronger than the low-value cue, researchers can then demonstrate that the PIT effect is moderated by the value of outcomes and is likely independent of strategic processes.

This question was empirically examined in two experiments by Qin et al., 2021 (see Chapter 2). In these experiments, participants first engaged in an Instrumental learning stage where they learned to earn low and high-value outcomes (e.g., coins of 5 or 20 cents) by pressing two different keys (e.g., left key leads to 5 cents and right key leads to 20 cents). Next, they received the Pavlovian learning stage, where they learned to associate two specific cues with one of the two coins (e.g., a picture of a 'star' with 5 cents and a picture of a 'wave' with 20 cents). In the following PIT test, they were forced to press the left or right key but prompted with the Pavlovian cues associated with the same/different outcome that was linked with the key press action. The data showed that participants responded faster when the cue and the action predicted the same outcome, and this effect was more pronounced in high-value coin conditions (Qin et al., 2021). This result thus indicates that the strength of goal-directed behavior evoked by cues is dependent on the value of the outcome (c.f., Custers & Aarts, 2005; 2007; 2010). Of importance, the studies also demonstrate the functionality of the S-R compatibility effect in testing cue-based goal-directed behavior.

PIT and testing socially meaningful goals

The PIT study discussed above represents an instance of cue-based goal-directed behavior in which participants earn money for themselves. It is important to note that human beings not only pursue goals that are essential for satisfying their own needs. They may also pursue goals with more social meaningfulness, such as pursuing a pro-social goal of earning money and donating it to people in need. Social goals can be broadly classified into two categories: those that serve self-interest (pro-self outcomes) and those that serve the interests of others (pro-social outcomes). Self-interest (vs. other-interest) is a powerful human need argued to dominate in most western cultures (Batson, 1994; Miller, 1999). Thus, people may allocate their resources towards personal benefits, such as purchasing luxury goods, or towards benefiting others, such as donating to a charity to help people in need. However, whether environmental cues can activate pro-social goals and resulting goal-directed behavior has not been fully tested.

Qin and colleagues conducted a series of experiments to examine cue-based goal-directed behavior for pro-self and pro-social outcomes. In a first study (Qin et al., 2023a; Exp 1; Chapter 3), participants learned to earn 10 cents coins for themselves (pro-self outcome) or for donating to one specific charity (pro-social outcome) by pressing the left or right keys. They then learned to associate two Pavlovian cues with the two outcomes. Using the forced-choice PIT test (Qin et al., 2021; Chapter 2), it was found that the PIT effect only occurred for the pro-self outcome (i.e., earning coins for themselves), while the PIT effect was absent for the pro-social outcome (i.e., earning coins for donating to a charity). Considering that pro-self (vs. pro-social) outcome goals are experienced to be more attractive, the findings may speak to differences in perceived value.

Interestingly, another possible reason for the stronger effects of the pro-self (vs. pro-social) outcome goals is the difference in freedom of spending the earned money. Specifically, the pro-self outcome condition was framed as an opportunity to spend the money on oneself as one wishes. In contrast, the money could be spent only in one way in the pro-social outcome condition, namely donating it to one specific type of charity. Research suggests that perceived freedom of choice, or autonomy, is a strong human need, and undermining it causes an undesirable state of mind (Deci & Ryan, 1985; Zhang et al., 2022). Taking this difference in perceived freedom into account, they conducted a second experiment (Qin et al., 2023a; Exp 2; Chapter 3) where participants could also decide themselves to which charity they wished to donate the money they would earn. And indeed, taking differences in freedom away caused the pro-social outcome goals to become under the control of cues as well. Accordingly, freedom of choice seems to render pro-social goals and outcomes in the interest of others more important.

In addition to the sociality (me vs. others) of goals, social goals can also be considered as being represented in hierarchically organized structures. In other words, actions can serve to fulfill various needs or achieve overarching goals (Geen, 1995; Kruglanski et al., 2002). For example, people might buy candy bars not only to satisfy their appetite but also as a gift for a friend or a token of praise. In this sense, multi-functionality (in comparison to single-functionality) is generally considered more valuable in responding to opportunities and demands posed by the social and physical environment (Bijleveld & Aarts, 2014; Kruglanski et al., 2015; Mikhalevich et al., 2017). However, it is unclear whether people's preferences towards multi-functional outcomes can be translated into cue-based behavior, which is triggered by representations of the desired outcome activated by environmental cues. Investigating this question may provide valuable insights into how cue-based goal-directed behavior operates for high-level goals, thus offering a more comprehensive understanding of this phenomenon.

The issue of multi-functionality in cue-based goal-directed behavior was investigated by Qin et al. (2023b; Chapter 4). Participants learned to earn two identical snacks (e.g., Snickers candy bar) by pressing one of two keys (left or right). One snack was framed as multi-functional (i.e., participants could consume it, give it to their friends and even exchange it with experimenters for money). Another snack was framed as single-functional (i.e., participants were only allowed to consume it directly after the experiment). Next, two different cues were linked to the two differently framed snacks. Using the forced-choice PIT test, it was found that participants responded faster to the cue associated with the multi-functional outcome frame than to the cue associated with the single-functional outcome frame, but only when the key and the cue shared the multi-functional outcome frame. This specific multi-functionality-based PIT effect was replicated in a second study, in which the timeframe of using the snack was controlled for.

Together with the results from Qin et al. (2023a; Chapter 3), these results indicate that cues can trigger behavior leading to socially meaningful goals, and PIT can be a tool to investigate such cueing effects.

Automatic goal pursuit: The distinction between action initiation and persistence

So far, I have presented research exploring the role of value of several goals in cue-based behavior. Our findings suggest that by and large, earning money and snacks that have multiple purposes for oneself or others can be considered strong incentives that readily turn people into cue-based automatic goal pursuers. Understanding cue-based goal pursuit requires examining not only the effects of pursuing different types of goals but also the cuing effect on goal-directed behavior itself. What do the cues actually set in motion? Do they direct responses, or do they also motivate behavior?

According to a process account of automatic goal pursuit, exposure to goal-relevant cues has two distinct effects on behavior (e.g., Custers & Aarts, 2010, Marien et al., 2015): First, the cue initiates the instrumental action as a result of priming the mental representation of the goal. Second, the person assesses the rewarding value or positive affect attached to the goal, motivating the individual to attain the goal. Accordingly, the full motivational nature of goal-directed behavior consists of two components: action initiation, which is the speed of selecting the appropriate action in response to the goal-relevant cues, and action persistence, which concerns the amount of effort invested in maintaining behavior and in achieving the goal (Aarts et al., 2004; Custers & Aarts, 2010; Geen, 1995; Gollwitzer, 1999; Marien et al., 2015).

Whereas there is evidence that cues can trigger goal-directed behavior under the PIT framework (e.g., Qin et al., 2021), it is less clear which component of goal-directed behavior is controlled by environmental cues. To demonstrate the full motivational nature of goal-directed behavior, it is important to assess whether cue-based control over behavior facilitates action initiation as well as action persistence to obtain desired outcomes.

This question was investigated in Qin et al. (2023c; Chapter 5) by measuring action initiation and action persistence in the test phase where the PIT effect can be observed. Participants were instructed to press a key multiple times on a keyboard to move a Pavlovian cue associated with a desirable outcome to the front of a hallway displayed on the computer screen. This setup employs the speed of decreasing the distance between the desired outcome and oneself as an indicator of action persistence, which is considered a hallmark of goal-directed motivation (e.g., Carver & Scheier, 1998). The first and the remaining responses can be used as action initiation and persistence indices, respectively (e.g., Marien et al., 2015). Results showed that only a PIT effect on action initiation was observed, but no effect on action persistence was found. This finding indicates that our adapted PIT paradigm can only partly assess cue-based goal-directed behavior as conceptualized in the automatic goal pursuit literature.

General discussion and conclusions

The present dissertation reports the findings of a research project that examined how cues in the environment can control goal-directed behavior. There is common agreement that the environment can have a strong and compelling effect on our behavior. Whereas such an effect is commonly considered to be a result of S-R habits (i.e., repetition of responses rewarded in the presence of stimuli), other research suggests that such S-R links are mediated by the representation of the outcome following the action. This model of cue-based goal-directed behavior has been argued to underly findings of automatic goal pursuit. Central to the idea of automatic goal pursuit is the assumption that goals are mentally represented in hierarchically ordered knowledge structures (Aarts & Dijksterhuis, 2000a; Hassin et al., 2009; Kruglanski et al., 2002). The representations of goals are assumed to include the environment or context, the goal, and actions as well as means that may aid goal pursuit. Several lines of research suggest that a variety of social goals, such as cooperation, making money, and socializing, are triggered by environmental cues and direct and motivate our thinking and doing in line with the goals.

Despite the empirical evidence supporting environmental control of goal-directed behavior (see for recent reviews, Dai et al., 2023; Weingarten et al., 2016), previous work on automatic goal pursuit does not properly distinguish between behavior that is activated directly by cues and behavior that is mediated by representations of desired outcomes (Custers & Aarts, 2010; Marien et al., 2019). That is, the cues used in these studies are associated with both the goal and the actions causing them. Therefore, strict tests to distinguish between the direct (habit) and indirect effects (goal-directedness) of cues on human behavior are scarce.

In the present project, we took advantage of another area of research that considers cue-based behavior to be mediated by goal representations. We adapted the PIT paradigm in an attempt to test whether and how goals can mediate cue-based behavior after instrumental and Pavlovian learning. PIT separates the learning of actions and cues and capitalizes on their shared overlap of rewarding outcomes. That is, actions and cues are both associated with rewarding outcomes, while there is no direct sensory-motor learning between actions and cues. Thus, the observation that cues trigger behavior can most likely be explained by the mediation of the representation of the outcome (or goal). In four chapters, including eight experiments, we found evidence for this notion of action-outcomes that are typically studied in the area of automatic goal pursuit, such as earning money and helping others. Considering the novelty of testing PIT as a way to understand the phenomenon of automatic goal pursuit, I will discuss a few issues that might be relevant to further examine the link between PIT and automatic goal pursuit.

Goal value, PIT, and automatic goal pursuit

Recent reviews show that the value of a goal is an important moderator in automatic goal pursuit. Goals with more value are more likely to mediate the effects of cue exposure on behavior. In terms of PIT, this means that the Pavlovian to Instrumental transfer is more pronounced for rewarding outcomes that are valued by the participants. There are two ways to examine this.

First, one of the most used methods is the outcome devaluation method (e.g., Allman et al., 2010; Eder & Dignath, 2016a; Hogarth & Chase, 2011; Seabrooke et al., 2017; 2019). In such a setup, participants engaged in an instrumental learning task in which they press keys (e.g., left or right) to earn two rewards (e.g., crisps or popcorn), and the two rewards are trained to be linked to two different Pavlovian cues. In a subsequent outcome devaluation procedure, one of the rewards is devalued (e.g., informing participants that one of the respective snacks is expired and no longer fresh). The typical finding is that, compared to the valued outcome cue, participants less often choose the response associated with the devalued outcome cue.

Another approach is the value comparison method, in which the value of rewarding outcomes is varied during learning (e.g., Jeffs & Duka, 2017; Watson et al., 2016). Here, participants learn to link two different outcomes of different values to two responses and two cues separately. Thus, cues associated with high-value outcomes are more likely to facilitate high-value outcome responses compared to cues associated with low-value outcomes and responses. Indeed, we (this thesis) and others have shown that compared to the high-value outcome cue, participants' responses associated with the low-value outcome cue are less or not facilitated.

Together, studies that rely on outcome devaluation and outcome value comparison methods point in the same direction: PIT and cue-based goal-directed behavior are a function of the value of the goal. This concurs nicely with recent reviews of automatic goal pursuit research.

It is important to note that most PIT studies with human subjects take place in a decision-making context. Decisions are usually made under consideration of choice options in the presence of relevant cues and can depend on preferences and framing (Slovic, 1995; Tversky & Kahneman, 1985). Choice measures thus represent strategic behavior resulting from explicit expectations in the task at hand (Qin et al., 2021). In an attempt to rule out the strategic decision process, we took a different approach by using the value-comparison method and testing specific PIT effects in a cue-based forced-choice response task (Qin et al., 2021; 2023a; b; c). We showed that participants were faster in selecting the outcome-related response when the cue and the response were associated with the same outcome, and this effect was stronger for high-value (vs. low-value) outcomes. Considering that the cue-based response time task builds on a response-priming process, which is less sensitive to strategic decision-making, our study explicitly demonstrates outcome value-based specific PIT effects. While we followed the value-comparison method for testing PIT, future research could explore how the cue-based forced-choice response task could be combined with the devaluation procedure to examine PIT effects. This would provide convergent validity for automatic goal pursuit on measures of preferences and speed of behavior.

On the origin of automatic goal pursuit: Value, freedom, and multi-functionality

So far, outcome value seems essential for cue-based goal-directed behavior to materialize. In PIT research, the role of value in the motivational control of goal-directed behavior is commonly understood in terms of sensory-affective responses to stimuli. Action-outcomes are rewarding and motivating to the extent that they give pleasure or satisfy needs. In the present research, we moved away from such basic sensory experiences as the root of motivation in cue-based goal-directed behavior. In line with research on automatic goal pursuit, we examined outcomes that involve high-level cognitive processes and are implicated in mental models of reasoning and knowledge representations (Gentner & Stevens, 2014; Johnson-Laird, 2010), such as earning money for oneself, taking care of others and spending rewards in multiple ways. That is, instrumental actions that are learned to be represented in terms of self-related and other-related interests have the capacity to evolve into goal-directed behavior that can be triggered by the environment.

Our studies address an important aspect of instrumental learning that is key to people's motivation to set and achieve goals. First, we established that gaining monetary outcomes in the interest of others is more sensitive to cue-based goal-directed behavior when individuals can decide how to spend the money on others. Apparently, having options (e.g., donating money to different charities) is perceived as more valuable than having no options (donating money to only one charity). Secondly, we showed that outcomes (e.g., earning a candy bar) that have multiple functions (e.g., eating it, giving it to someone, returning it for money) are more likely to serve as a goal and mediate the link between cues and behavior. The general theme here is that perceived *freedom of choice* and autonomy fosters automatic goal pursuit compared to when one is forced to act and restricted in autonomy. This is in line with research that has studied the relationship among choice, motivation, and performance (e.g., Patall et al., 2008; see Zhang et al., 2022, for a functional analysis of personal autonomy).

Interestingly, recent research has started to explore sensorimotor and neural processes involved in the relation between choice and goal-directed behavior, and the tentative findings suggest that lack of choice dampens the involvement of brain areas that are implicated in the experiences of agency and the conscious control of goal-directed behavior (e.g., Barlas, 2019; Barlas & Obhi, 2013; Caspar et al., 2016, 2017; Filevich et al., 2013; Tanaka & Kawabata, 2021). Choice thus alters the neurocognitive process of cue-based goal-directed behavior in humans. These findings raise the question of how choice plays a role in the distinction between cue-based habits and goal-directed behavior.

A possible answer could be found in differences in cognitive processing during learning and decision-making (e.g., Katz & Assor, 2007; Payne et al., 1993). First, knowing that one has only one action-option (e.g., buying a snack) to attain a goal (e.g., spending money) might render learning shallow and associative, causing behavior in context to result from simple reinforcement learning. Under such conditions, people might more readily form S-R habits that gradually become detached from the rewards. However, when people are aware of having more freedom of choice, they process information about their actions, outcomes, and the environment more deeply and attentively and make more mental links between them. Such learning might be based on propositional knowledge (Mitchell et al., 2009), leading to instances of cue-based goal-directed behavior that are integrated into high-level cognitive processes. In this view, automatic goal pursuit originates from a sense of agency that accompanies perceived choice (Renes & Aarts, 2018). Of importance, this proposed role of perceived choice in distinguishing habit learning from cue-based goal-directed behavior learning is highly speculative and needs further attention in future research.

The motivational nature of cue-based goal-directed behavior

In Chapter 5, we explicitly examined the full motivational nature of cue-based goal-directed behavior, according to which cues set the stage for two succeeding action-process steps: (a) cues ease the initiation of selected goal-directed actions, and (b) once initiated, people persist in behavior -- even when extra effort is required. Existing PIT studies with humans examine action performance (choice or speed) in response to Pavlovian cues, but action persistence is usually not the target of testing. In an adaptation of the PIT test, we operationalized (a) action initiation as the speed of selecting the required response upon exposure to the cue and (b) action persistence as the speed of performing a sequence of steps to decrease the distance between a cue and oneself, representing the attainment of the goal at issue.

Earlier research on automatic goal pursuit suggests that effort investment is an important part of the process of goal achievement. However, this aspect is often measured in tasks that confound initiation and persistence in selecting goal-directed actions (e.g., Capa & Custers, 2014; Gendolla & Silvestrini, 2010). Separating initiation from persistence requires an action-effort task that clearly distinguishes the preparation of action from the motivation of action (Aarts et al., 2008; Marien et al., 2015; Takarada & Nozaki, 2018). Whereas our test was built on such an action-effort task, we found support for action initiation but not for action persistence. Within the context of our experimental setup and the test task, the results suggest that cues associated with rewarding outcomes only partly motivate cue-based goal-directed behavior.

The absence of the specific PIT effect on the persistence measure may indicate that participants were not willing to spend the effort to get the reward. Research on the behavioral, neurophysiological, and computational implementation of effort suggests that effort investment is subject to resource conservation: Individuals are motivated to avoid wasting energy and time and aim at investing resources only for outcomes that are attainable and do matter (Bijleveld et al., 2012a; Brehm & Self, 1989; Chong et al., 2017; Lopez-Gamundi et al., 2021). Accordingly, the absence of a specific PIT effect on the component of action persistence might stem from the specific nature of the operation of outcomes in our research.

One important reason for the absence of the PIT effect on persistence speaks to the value of outcomes. The present studies (Qin et al., 2023c; Chapter 5) used two monetary outcomes of different values (i.e., 5 vs. 20 cents) that were each linked to a specific Pavlovian cue. Whereas the 20 cents value outcome is four times more worth than the 5 cents value outcome, it might be the case that the difference between the two values is too small to motivate participants to invest effort. In light of this, it might be informative to note that action initiation effects did not show up when the learning context was different from the test context (see the supplementary materials, Appendix D) but emerged only when the learning and testing contexts were closely aligned.

Another possible reason that PIT did not affect the persistence of action pertains to the question of how participants represented the cues. Based on the PIT phenomenon, we capitalized on the notion that the cues would represent low vs. high-value outcomes, and thus the high (vs. low) value outcome cue would enhance the motivation to get them. However, it is important to note that in the present study, participants were told that no actual monetary outcomes were at stake in the test task. The explicit knowledge about the inability to gain actual outcomes might have had a price. Participants initially considered the cues as having value but then realized during action repetition that they were just stimuli. Thus, it is likely that the cues only initiated action, as working for stimuli that have no actual value is a waste of energy.

This explanation resonates well with findings from coin priming research (Zedelius et al., 2013; 2014). In one study (Zedelius et al., 2013), participants performed a series of effortful working memory tasks, which require cognitive effort. Before each task, they were exposed to a high (50 Euro cents) or low-value (1 Euro cent) coins cue and told that the coins were actual rewards for good performance or that they were just stimuli. Results showed that the value of the coins did enhance the task performance when the coin cues were represented as rewards but not as mere stimuli. It might be worthwhile to stress that stimuli can be motivating in themselves, which is backed up by previous findings on the auto-shaping of behavior (Brown & Jenkins, 1968; Williams & Williams, 1969) and by more recent research on implicit affective conditioning (Custers & Aarts, 2005; Marien et al., 2015). Accordingly, an important step could be to explore this further by manipulating the relevance of cues as a signal for goals when testing automatic goal pursuit in the PIT paradigm.

It is important to note that although we mainly discussed our findings in the light of our own paradigm, there may be more general issues that have implications for the literature on PIT and cue-based goal-directed behavior in general. First, the finding that outcome value moderates the PIT effect is a clear sign that outcome representations (that include outcome value) play a key role in the PIT effect. While this points to the involvement of motivational processes, this effect seems – at least in works reported here – limited to action initiation. In this sense, cues give the behavior a push in the right direction, but given the lack of persistent effort to attain the outcome, the process – while motivational – may be more ballistic in nature. That is, it may not involve monitoring and feedback processes, which are the hallmark of goal-directed behavior (e.g., Carver & Scheier, 1998). Rather, cues may just evoke recruitment of effort that boosts behavior in a specific direction (Bijleveld, 2012b; Custers & Aarts, 2010; Custers et al., 2012).

There are several observations from the PIT literature that fit such an account. First of all, behavioral effects in animals and humans are often quantified in terms of response frequency. While this may be a sign of motivation, it does not speak against the boosting account. Second, while the observation of general PIT (cues motivate any action) has puzzled researchers for a long time (Cartoni et al., 2016), this phenomenon fits the boosting account perfectly, but not the goal-directed account. Investigating the distinction between boosting and goal-directed motivational behavior in PIT effects may therefore be an important avenue for further research on PIT in general.

Conclusions

The findings of the present thesis suggest that environmental cues guide individuals to select their responses swiftly in the presence of cues that represent socially meaningful goals. While PIT effects resemble the process underlying people's biases toward responding to outcome-related cues, the reported research here suggests that PIT does not necessarily translate into effortful behavior as a function of modulating the motivational salience of the cues. The importance of motivation of action to achieve goals in everyday life seems obvious. We believe that the PIT paradigm is a promising tool for studying how cues motivate goal-directed behavior – and, thus, how automatic goal pursuit may emerge. Future research could further address key aspects, such as the value and representation of cues and outcomes, when considering the full motivational nature of human behavior and understand whether and how cue-based behavior is driven by habits or mediated by goals.

Overview of the chapters

The remaining chapters (i.e., Chapter 2-5) present the empirical studies reported in the introduction. All chapters utilized specific PIT tests to investigate whether cues associated with motivational properties facilitate goal-directed behavior based on an RT-based forced-choice paradigm (e.g., Qin et al., 2021). More specifically, Chapter 2 presents an RT-based forced-choice paradigm in which we implemented a direct comparison between cueing effects induced by high and low-value outcome cues. Chapter 3 builds on the essence of pro-self and pro-social motives in humans and explores whether the cue-based behavioral effect can occur when encountering cues associated with pro-social outcomes (e.g., earning coins to donate). Chapter 4 assessed whether the outcomes associated with multiple functions (vs. a single function) can trigger a stronger cue-based effect. Chapter 5 explored whether the observed cue-based effect can be found in the initial stage of goal-directed behavior (action initiation) as well as in action persistence. Please note that these chapters can be read separately or subsequently because they have been written as individual articles that have been published as such.

CHAPTER
2

Chapter 2:
Environmental control of human goal pursuit: Investigating cue-based forced responses in a Pavlovian-to-instrumental transfer paradigm

This chapter is based on: Qin, K., Marien, H., Custers, R., & Aarts, H. (2021).Environmental control of human goal pursuit: Investigating cue-based forced responses in a Pavlovian-to-instrumental transfer paradigm. *Motivation Science*, *7*(3). 281–290. https://doi.org/10.1007/s12144-023-04612-2

Credit author statement:

KQ: Conceptualization, Methodology, Investigation, Writing-Original-Draft, Writing-Review & Editing, Visualization. **HM**: Conceptualization, Methodology, Writing-Review & Editing, Supervision. **RC**: Conceptualization, Writing-Review & Editing. **HA**: Conceptualization, Methodology, Writing-Review & Editing, Project administration, Supervision.

Abstract

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 reaction times 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, reaction times, value, goal-directed behavior, forced-choice

Introduction

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 of socializing, 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 for investigating 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).

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 either gain 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 towards 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 data were less clear. While the reaction time data of the first experiment demonstrated that the specific PIT effect is stronger in the high-value condition, the reaction time 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 outcomes 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).

[1] PIT studies generally employ three sub-categories: non-selective PIT, general PIT, and specific PIT (Holmes et al., 2010; Mahlberg et al., 2021). Specific PIT paradigms are designed to test goal-directed behavior.

Specific PIT effects were assessed by testing choice in response to Pavlovian cues that predicted the low vs. 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 cues that predict high-value outcomes are presented, 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 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-value outcomes trigger responses more strongly than cues associated with low-value outcomes.

For this purpose, we designed an experimental setup consisting 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 to the reaction time 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 vs. non-related 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 a 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 vs. 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-value outcome condition compared to the low-value outcome condition. The data and all analysis scripts are available on OSF (https://osf.io/ta4hc).

Experiment 1

Method

Participants and design

42 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 the 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 received a fixed amount of €2 afterward. They 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 6x4-meter soundproof cubicle, facing a computer screen (1920*1080), 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 grey 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 grey square and served as imperative stimuli for responses. Full-color images of a 5-cent and 20-cent euro coin (visual angle 6.60°) served as outcomes during the 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 rewards 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 4 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 grey square would appear in the center of the screen for 1-3 seconds (random time interval), and then a blue or yellow frame would appear until response. Upon response, participants would either speak out ‘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 second. Participants first performed 20 practice trials, and although they would not yet earn real money during practice trials, they could 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 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

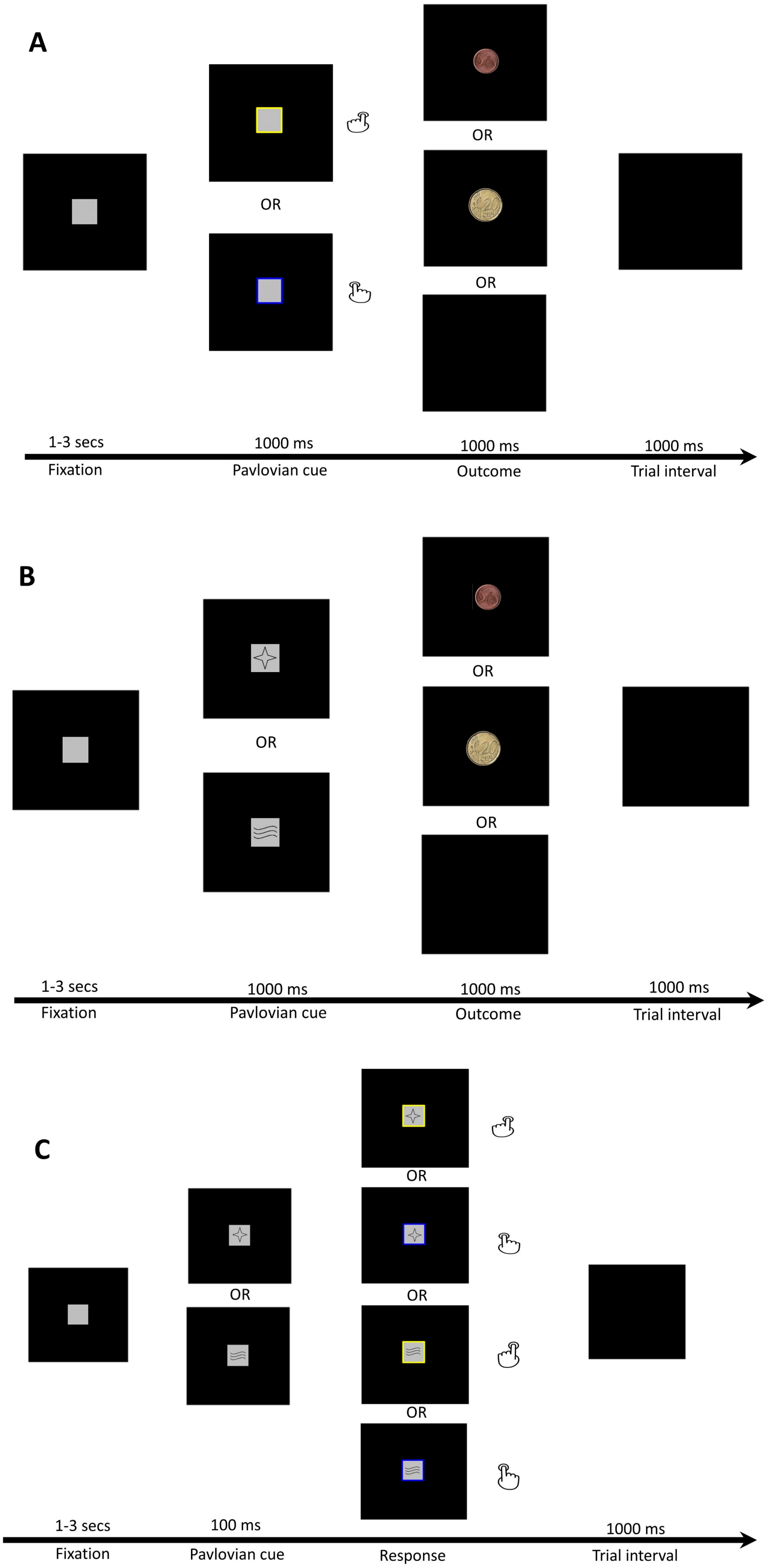

Figure 1. Instrumental learning (A), Pavlovian Learning (B), Test Phase (C)

Pavlovian learning phase. In the Pavlovian learning phase, participants did not press any keys. Furthermore, no colored frames appeared around the grey square, but only the cues (a ‘star’ or ‘wave’) appeared inside of the grey 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 grey square appeared for 1-3 seconds (random time interval), then a ‘star’ or a ‘wave’ would appear for 1 second. Upon presentation of these cues, participants would either speak out ‘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 second. 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 performed in the first phase (i.e., the demonstration phase). Additionally, participants would not need to speak out the predicted rewards anymore but just respond as quickly and accurately as possible to the imperative stimuli. In each trial of the task, a grey 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

[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 Supplemental Materials (Appendix A) in the contingency learning sections for both experiments.

‘star’ or ‘wave’) appeared inside of the grey square after a 1-3 seconds randomized time interval. After a further 100ms, a yellow or a blue frame would appear surrounding the grey 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 second 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

Firstly, 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 (Details see the supplementary materials, Appendix A). 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, -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 supplemental materials, Appendix A). 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, +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. This effect should be more pronounced in the high-value condition.

Results

Reaction times in the test phase

The pattern of reaction times is presented in Figure 2[3]. The planned contrast was significant (F (1, 39) = 6.49, p = .015, η_p^2 = .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. 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.

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

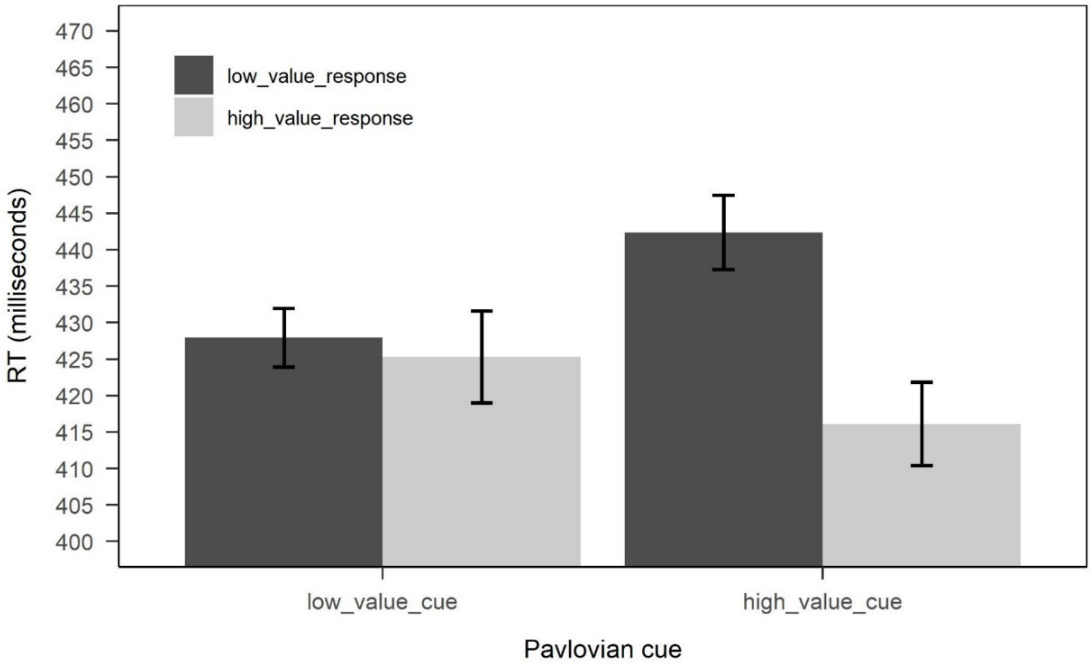

Figure 2. Reaction times in the test phase of Experiment 1 as a function of Cue outcome value and Response outcome value. Error bars represent one standard error of the mean[4].

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.

[4] All presented figures' error bars in this thesis have been corrected based on adjusted values for taking within-subject variances into account(Morey, 2008)

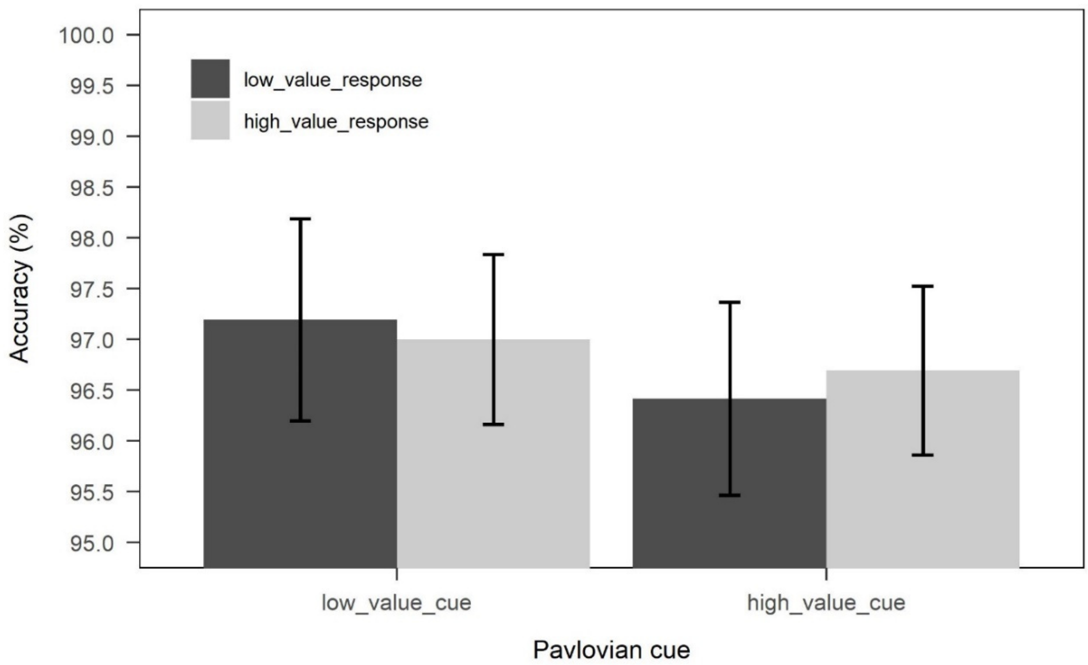

Figure 3. Accuracy in the test phase of Experiment 1 as a function of Cue outcome value and Response outcome value. Error bars represent one standard error of the mean.

Discussion

Although the significance of the planned contrast test with a medium effect size ($\eta_p^2 = .14$) 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 by 15 extra participants. Thus we recruited 57 undergraduate students for Experiment 2. Data from one participant were excluded from the analysis because the RT data were excessively slow (>3 *SD* from the 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 received a fixed amount of €1 afterward. They 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 phases 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 4 blocks of 40 trials, so 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 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 supplemental materials, Appendix A), 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 supplemental materials, Appendix A). 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, η_p^2 = .07 [0.002; 0.205]).

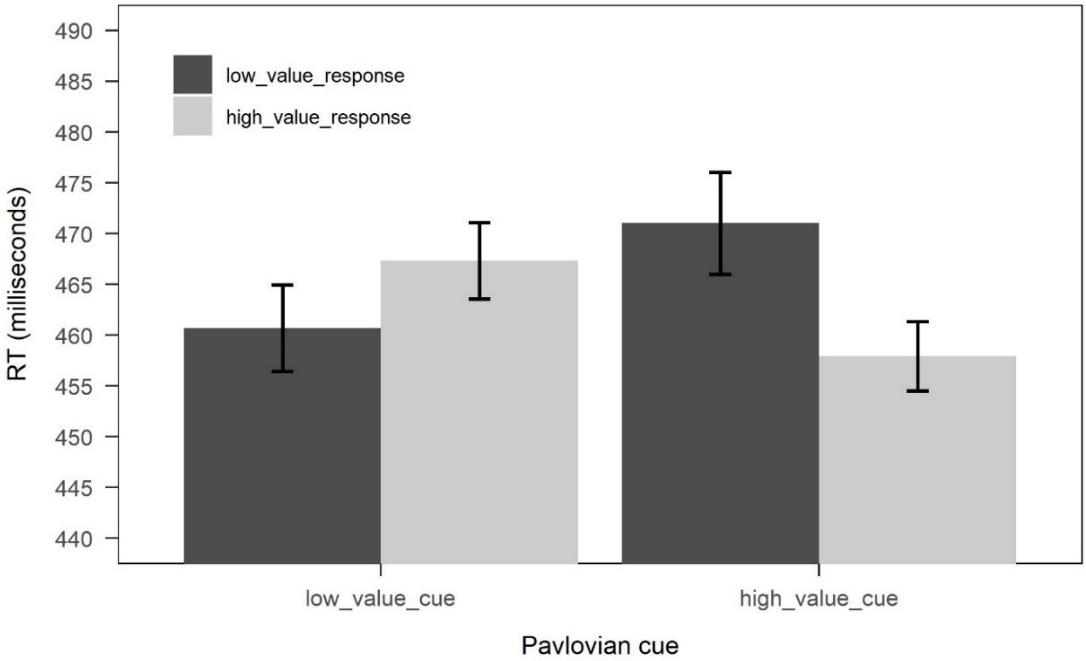

Figure 4. Reaction times in the test phase of Experiment 2 as a function of Cue outcome value and Response outcome value. Error bars represent one standard error of the mean.

Accuracy in the test phase

The pattern of accuracies is presented in Figure 5. The planned contrast was significant, $F\,(1, 55) = 7.36$, $p = .009$, $\eta_p^2 = .12$ [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 than when the cue and the response predicted different outcomes. This effect was more pronounced in the high (50 cents) outcome value cue condition.

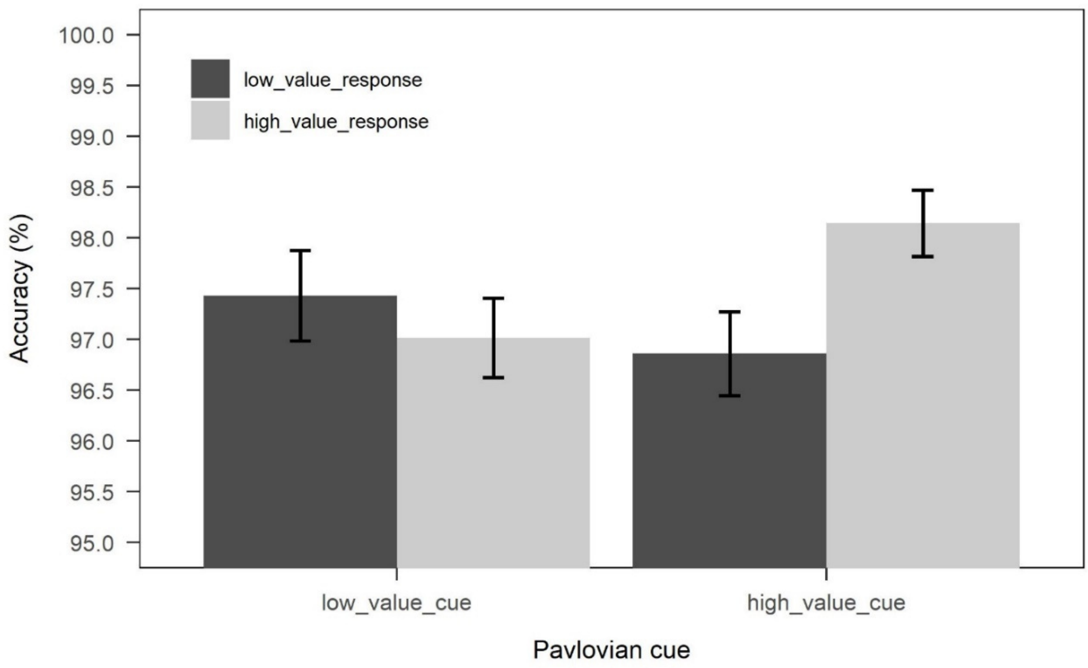

Figure 5 Accuracy in the test phase of Experiment 2 as a function of Cue outcome value and Response outcome value. Error bars represent one standard error of the mean.

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 than 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 reaction times (η_p^2 = .07) that seems smaller than Experiment 1(η_p^2 = .14). However, Experiment 2 did yield an effect on accuracy with a medium effect size (η_p^2 = .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 reaction times 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., 2021; 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 vs. 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-value 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-value 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 important outcomes.

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-value outcome cue more often than the response of the low-value outcome cue. However, high-value outcome cues evoked slower responses than low-value outcome cues (Watson et al., 2016 Experiment 2), indicating a reversed specific PIT effect. In another study (Jeffs & Duka, 2017), participants preferred low-value outcome responses to cues linked to the low-value outcome and high-value outcome responses linked to the high-value 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 to the current debate on whether PIT is goal-directed or habitual (Mahlberg et al., 2021). 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 has no longer 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, 2016a), 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 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 in incompatible trials. Whereas such stimulus-response compatibility effects are thought to ensue from response facilitation and/or interference (Hübner & Töbel, 2019; Simon & Acosta, 1982), it is not clear from our findings which of these two processes are responsible for the value-based PIT effect. One needs to include a baseline condition with a neutral cue to address this issue more specifically. 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.

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, et al., 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 towards 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.

CHAPTER
3

Chapter 3:

Environmental control of social goals: Using Pavlovian-to-instrumental transfer to test cue-based pro-self and pro-social outcome responses

This chapter is based on: Qin, K., Marien, H., Custers, R., & Aarts, H. (2023a). Environmental control of social goals: Using Pavlovian-to-instrumental transfer to test cue-based pro-self and pro-social outcome responses. *Royal Society Open Science*, *10*(1). https://doi.org/10.1098/rsos.220660

Credit author statement:

KQ: Conceptualization, Methodology, Investigation, Writing-Original-Draft, Writing-Review & Editing, Visualization. **HM**: Conceptualization, Methodology, Writing-Review & Editing, Supervision. **RC**: Conceptualization, Writing-Review & Editing. **HA**: Conceptualization, Methodology, Writing-Review & Editing, Project administration, Supervision

Abstract

A large amount of literature demonstrates that social behavior can be triggered by environmental cues. A long-standing debate involves the question of whether such stimuli trigger behavior directly (i.e., habits) or whether these effects are mediated by goals. As studies on automatic goal pursuit typically use real-world cues that are already associated with the behavior and potentially the goal, it is impossible to make strong claims about the nature of the effects. In the present paper, we use a paradigm inspired by the Pavlovian-to-instrumental transfer (PIT) literature to examine how the environment can trigger goal-directed behavior. Building on the essence of pro-self and pro-social motives in humans, two experiments explored the PIT effect when the outcomes were framed in terms of self- vs. other-interest. Participants performed actions to earn money for themselves or a charity. Each outcome was linked to a different cue. The results showed that a cue predictive of self-interest outcomes facilitated responses instrumental in gaining the outcome, while such specific PIT effect for other-interest outcomes only emerged when participants were free to donate the money. We briefly discuss these findings reflecting on whether the PIT effect in our paradigm is indeed sensitive to the value of social goals.

Keywords: Goals, monetary rewards, self-interest, other-interest, Pavlovian-to-instrumental transfer

Introduction

An important question addressed in psychology is how the environment can control reward-seeking behavior. The notion that behavior is shaped by environmental stimuli is key to behaviorist approaches to habit learning (Watson, 1925; Skinner, 1953), according to which habits are formed when a motor behavior (e.g., pressing a lever) is repeatedly executed and reinforced in response to the same stimulus (e.g., a drop of sweet water). Whereas habit accounts have dominated the understanding of environmental control of behavior for many years (see Marien et al., 2019), more recent studies reveal that cues can trigger behavior indirectly. According to this research, cues activate mental representations of outcomes that lead to the execution of actions instrumental in attaining outcomes (Custers & Aarts, 2010; de Wit & Dickinson, 2009; Hassin et al., 2009; Loersch & Payne, 2011). In other words, environmental control of reward-seeking behavior seems to be mediated by goals.

Although in the classic work on environmental control of behavior, rewarding outcomes are usually related to eating and drinking (Corbit et al., 2007; Estes, 1943; Holland, 2004; Lovibond, 1983), people often pursue rewarding outcomes that are social in nature (Schacter et al., 2007; Suddendorf & Corballis, 2007). In general, the social goals that people aim to attain are directed towards two types of outcomes: goals that serve self-interest (pro-self outcomes) and goals that serve the interest of others (pro-social outcomes). For instance, people might spend their money for their own benefits (e.g., buying valuable consumer goods to increase their social status) or share it with others (e.g., donating to a charity to help people in need). It is not clear, however, whether such social goals and resulting behavior can be controlled by the environment as well.

Understanding cue-based control over people's engagement in pro-self or pro-social behaviors is highly relevant for various societal issues, such as social inequality, public health hazards, and environmental issues. It has been suggested that, especially when goals are repeatedly and consistently pursued by instrumental actions, activating the representation of the goal may trigger these instrumental actions (Bargh et al., 2001; Bargh et al., 2012). This way, people would engage in goal-directed behavior (e.g., spending money on oneself or others) without much deliberation and thought. Recent review studies reveal that behaviors linked to social goals can indeed be activated by the environment, and these effects are stronger for actions that produce more valuable outcomes (Jung et al., 2020; Weingarten et al., 2016). Therefore, cue-based control of behavior may not be understood as purely habitual but as mediated by activating representations of desirable outcomes or goals.

It has been pointed out, though, that while these studies hint at the involvement of goal representations, previous work on automatic goal-pursuit does not properly distinguish between behavior that is activated directly by the cues and behavior that is mediated by representations of desired outcomes (Custers & Aarts, 2010; Marien et al., 2019; Watson et al., 2018). That is, the cues used in these studies are usually associated with both the outcome and the instrumental actions leading to them in daily life. Therefore, it is impossible to distinguish between the direct and indirect effects of cues on behavior. To address this shortcoming, we turn to the literature on Pavlovian-to-instrumental transfer (hereafter abbreviated as PIT), which addresses this question in animal research (Corbit et al., 2007; Estes, 1943; Holland, 2004; Lovibond, 1983) precisely but also in humans, albeit with non-social behavioral outcomes (Eder et al., 2016a; Seabrooke et al., 2017; Talmi et al., 2008).

Here, we report an initial test inspired by the classic PIT paradigm that examines whether environmental cues can trigger behavior through pro-self and pro-social goals. Fundamentally speaking, cue-based goal-directed behavior relies on two distinct learning processes. First, people need to represent their behavior in terms of outcomes so they can anticipate these outcomes and direct their actions accordingly (Shin et al., 2010). Second, people need to understand that the cue represents an opportunity to obtain the outcome in the current situation (Blanco et al., 2010; Vadillo et al., 2005). The classic PIT paradigm experimentally separates these processes into two learning phases: the instrumental learning phase, in which the response is learned to produce an outcome, and the Pavlovian learning phase, in which a cue is learned to predict the same outcome. This way, the Pavlovian cue and response share the same outcome, allowing people to mentally link the cue and response through the shared outcome representation. The typical finding is that subsequent exposure to the cue facilitates the instrumental response (e.g., perform the response faster or more frequently), even though the response is never executed in the presence of the cue. The explanation for this effect is that the cue activates the outcome representation, which in turn triggers the instrumental response: the PIT effect. Importantly, using two distinct test procedures (i.e., outcome devaluation and high vs. low-value outcome comparison), PIT seems more pronounced for outcomes that are represented as having a high value, indicating that relatively strong (vs. weak) desirable goals are more likely to be controlled by the environment

(Mahlberg et al., 2021). These value-based PIT effects have been demonstrated initially in animals (e.g., Corbit et al., 2007; Holland, 2004) but lately also in humans (e.g., Eder et al., 2016a; Seabrooke et al., 2017; Talmi et al., 2008).

Pro-self and pro-social motives are central to everyday human interactions, particularly people's goal to earn money for themselves (self-interest outcomes) vs. earning money for others (other-interest outcomes). A well-established observation is that people are highly motivated to seek rewards for self-interest purposes (Batson, 1994; Campbell, 1975; Mansbridge, 1990). The rationale underlying this notion relies on classical conceptions of self-interest from evolutionary biology (genetic selfishness to increase an organism's fitness), economics (i.e., rational self-interest), and philosophy (i.e., psychological egoism). The general gist here is that pro-self goals are dominant in social contexts that yield a conceivable self-benefit, such as earning money for oneself. In contrast, it seems less important for individuals to earn money for others, especially when financial rewards for themselves (self-interest outcomes) are available (Bénabou & Tirole, 2006; Lacetera & Macis, 2010). Hence, when individuals can attain self-interest and other-interest goals within the same context, they likely attach a higher value to self-interest outcomes than other-interest outcomes.

Evidence that the environment can trigger self-interest oriented behavior comes from a recent meta-analysis on the concept of automatic behavior (Weingarten et al., 2016). Analyzing data from 133 studies, this study suggests that behavior that serves self-interest can be triggered automatically by cues that refer to pro-self goal concepts such as striving for power, status, or personal achievement. Such cue-based behavior is more pronounced when the goal is perceived as a valuable outcome. Furthermore, whereas pro-self behavior might be the default in the social context that clearly yield a self-benefit outcome, there is some research showing that cuing concepts related to pro-social goals (e.g., cooperation, helping) influences the decision made in these settings in favor of the pro-social outcome, as revealed by increased helping or donation behavior (e.g., Custers et al., 2008; Kleiman & Hassin, 2011; Loersch et al., 2008; Macrae & Johnston, 1998). Such pro-social automatic goal-pursuit might stem from intuitive processes shaped by successful strategies in social interactions and the internalization of cultural norms (Rand et al., 2012).

It is important to note that previous studies on pro-social automatic goal-pursuit suffer from a few methodological weaknesses that undermine the conclusion that cue-based social behavior is mediated by pro-self or pro-social goals. In a typical experiment, participants are exposed to words (e.g., power, help) or pictures (e.g., a ten-dollar note) that are assumed to trigger goals associated with them. Effects of the word or picture exposure (compared to a control condition) are then tested on the speed or direction of goal-related behavior using a response time or choice task. Furthermore, in some studies, the value of the goal is measured as an individual difference variable to examine whether automatic goal pursuit is more pronounced for goals that have value and matter to people. The automatic goal-pursuit effects are interpreted as being caused by the mediation of the mental representation of the goal. The words or pictures are supposed to trigger the representation of the high (vs. low) valued outcome, which in turn activates the resulting action. Although suggestive, these results are not conclusive regarding the mediating role of goals: The participants in these studies show performance on a behavioral measure after seeing words or pictures, but these effects do not attest to the basic assumptions that are argued to underly cue-based goal-directed behavior. That is, we do not know for sure whether participants did learn (1) to represent their behavior in terms of high-valued outcomes that they produced by the behavior and (2) did learn that the cue predicts the same outcome. We argue that previous research did not take these basic learning aspects sufficiently into account and suggest that a PIT approach may provide an important additional test to examine whether cue-based behavior is mediated by the representation of pro-self or pro-social goals.

Most PIT studies with human subjects rely on a decision-making task, asking participants to select one of two actions in response to a Pavlovian cue. In this context of choice options, decisions usually depend on preferences and framing in the presence of decision-relevant cues (e.g., Slovic, 1995; Tversky & Kahneman, 1981). Choice measures thus represent strategic behavior resulting from explicit beliefs and expectations that can bias choices in the PIT task due to demand characteristics (Qin et al., 2021). To rule out such strategic decision process, a few studies have tested value-based PIT effects in a cue-based response time task (Qin et al., 2021; Watson et al., 2016). For example, Qin et al. (2021) designed a cue-based forced-choice response time PIT test that measures the speed of responding with instrumental action in the presence of Pavlovian cues. This measure thus does not rely on a decision-making process but capitalizes on response facilitation upon being exposed to response-related cues. Employing a high vs. low-value outcome comparison procedure, participants could press a left or right key to earn low or high-value monetary rewards. The rewards (coins of 5 Euro cents or 20 Euro cents) were presented on the computer screen each time they pressed the correct key. In a Pavlovian learning task, participants learned to associate the two different coins with two new neutral cues. In the following test task, participants were briefly exposed to one of the Pavlovian cues, followed by the requirement to press the left or right key as fast as possible. Results of the test task showed that participants responded faster when the response and the cue predicted the same outcome, while the response was not directly executed in response to the cue. Moreover, this effect was more pronounced for high-value (vs. low-value) outcomes, thus showing a value-sensitive specific PIT effect. Similar effects have been found with multiple food outcomes that differ in value (e.g., Watson et al. 2016).

We report two experiments that adapted the procedure of Qin et al. (2021) to the context of pro-self and pro-social goals. In both experiments, using a within-subject design, participants could earn a small monetary reward with either self-interest or other-interest meaning. The self vs. other-interest meaning was manipulated in instrumental and Pavlovian learning phases. Specifically, in Experiment 1, participants pressed the left (R1) and right (R2) keys, which resulted in earning 10 Euro cents coin for themselves (O1) or for others by donating it to a charity (O2). Furthermore, in the Pavlovian learning phase, each outcome was linked to one of two stimuli (S1 and S2). Accordingly, the Pavlovian cue (S1) and response (R1) share the same outcome (O1), and the Pavlovian cue (S2) and response (R2) share the same outcome (O2). Importantly, participants do not learn to respond with R1 to S1 or with R2 to S2. They can, however, mentally link the cue and response through the shared outcome representation. This allowed us to test whether a Pavlovian cue associated with self-interest vs. other-interest outcome will speed up the corresponding response in the forced-two response time test (Qin et al., 2021). If the cue associated with the self-interest outcome speeds up the respective instrumental response, but the cue associated with the other-interest outcome does not, this will demonstrate that cues mainly trigger pro-self (vs. pro-social) goals and resulting behavior as they are represented as high-value self-interest outcomes, at least in the value-based PIT framework. Experiment 2 aimed to explore whether we can render other-interest outcomes as valuable as self-interest outcomes, providing further evidence that the social meaningfulness of the value of the same monetary reward can produce specific PIT effects.

Experiment 1

In Experiment 1, we examined whether participants' responses are facilitated by Pavlovian cues predicting a single valuable outcome and whether this effect is stronger for self-interest represented outcomes than other-interest represented outcomes. The self-interest outcome was operationalized as earning 10 Euro cents for oneself, whereas the other-interest outcome was operationalized as earning 10 Euro cents for a charity, namely the Against Malaria Foundation (a foundation that can provide mosquito nets donations). We chose this charity because donations are typically provided in small amounts of money (i.e., €2), which enabled participants to earn enough money during the experiment to provide an effective donation. Given that the self-interest and other-interest outcomes both consist of the same objective reward before the test phase (i.e., both are 10 cents euro coins), but the self-interest outcome is considered to have more subjective value than the other-interest outcome in the current context, we expected a cue-based facilitation effect to occur for the self-interest outcome but not for the other-interest outcome.

Method

Participants and design

Participants were recruited by posting advertisements that targeted English-speaking students under the age of 35. The required sample size for testing the cue-based facilitation effect was determined using G*Power analysis (Faul et al., 2007). We aimed to detect a medium effect size (η_p^2 = .10; based on previous research, Qin et al., 2021) with a power of 0.80 and used 3 measurements for the 2 x 3 within-subjects design test and epsilon = 1. The sample size analysis indicated that in the current experiment, at least 46 participants were needed. Concerning the possible dropout, we decided to recruit two more participants. Finally, forty-eight participants (mean age 24.5; 34 females) were recruited. We excluded data from one participant for not following the instructions. The remaining participants participated in the experiment with a 2 (Response outcome: self-interest vs. other-interest) x 3 (cue outcome: neutral vs. self-interest vs. other-interest) repeated measures design. The neutral cue was used as a baseline to control for differences between the speed of self-interest and other-interest responses. Participants received a show-up fee of €2 and could earn €4 (€2 extra for themselves and €2 extra for the charity).

Apparatus and materials

Participants were placed at a desk in a soundproof cubicle facing a computer screen, and a standard keyboard was in front of them. The experiment was programmed in MATLAB with Psychophysics Toolbox Version 3.0.10 (Brainard, 1997). The monitor screen (1920*1080 pixels) presented a black background and projected instructions in white. During the task, a grey square (RGB 192 192 192, visual angle 6.60°) appeared in the center of the screen. Three simple figures (i.e., a 'star', a 'cloud', and a 'moon', visual angles 6.60°) were presented in the center of the grey square. A yellow frame (RGB 255,255,0 visual angle 6.86°) and a blue (RGB 0,0,255 visual angle 6.86°) frame surrounding the grey square appeared as prompts for responses. The self-interest and other-interest outcomes used in the learning phases were depicted by a full-color image of a 10-cent euro coin dropping in a piggy bank. To support participants in representing the money as being self vs. other-relevant, the word 'ME' (representing the self-interest outcome) or 'NETS' (representing the other-interest outcome) was printed on it. The word NETS was used to refer to the mosquito nets that the Against Malaria Foundation can buy from the donations.

Procedure

Participants signed the informed consent upon arrival at the laboratory. The experimenter told participants that the study contained several tasks, and they could earn extra money for themselves and the Against Malaria Foundation to help people under the threat of malaria (see supplemental materials, Appendix B for complete information about the charity provided to participants). The experimenter stayed in the cubicle during the entire experiment and sat behind a divider screen to monitor the procedure and task performance of the participant during the experiment. The experiment contained four phases: a demonstration phase, an instrumental learning phase, a Pavlovian learning phase, and a test phase.

Demonstration phase. The experiment started with a demonstration task to familiarize participants with the speeded response task (details see the test phase). They performed 42 trials in total.

Instrumental learning phase. Participants learned that they could earn money for themselves (the self-interest outcome) or a charity (the other-interest outcome) by correctly producing two different motor responses. Participants first practiced 20 trials (block 1), followed by 20 real trials (block 2). The trials in the practice and the actual task were randomly presented, and each condition (i.e., the self-interest outcome response and the other-interest outcome response) was repeated 10 times in each block.

The trial procedure is depicted in Figure 1 (panel A): Each trial started with a grey square for 1-3 seconds (random time interval), then a yellow or a blue frame indicated to press the left or right key. Participants could earn 10 cents for themselves by correctly pressing the (left) 's' key (yellow frame) and 10 cents for the charity to buy malaria nets by correctly pressing the (right) 'k' key (blue frame); colored frames were counterbalanced across participants. After a correct keypress, the self-interest outcome or other-interest outcome (represented by the picture of a 10 cents coin dropping in a piggy bank) was presented for 1 second. To support participants in keeping the self vs. other-interest outcome in mind, the picture of a 10 cents coin and a piggy bank also displayed the word 'ME' or 'NETS'. To encourage participants to carefully process the outcome information, they had to speak out '10 for ME' or '10 for NETS' when pressing the corresponding keys. The experimenter took note of whether participants spoke out the correct outcome.

Participants did not know how many trials they had to do and how many they had executed correctly. After the task, they were told how much money they had earned. We decided to give all participants the same amount of extra money: €2 (€1 for themselves and €1 for the Against Malaria Foundation). Actual earnings thus were independent of performance.

Pavlovian learning phase. In this phase, participants learned that they could earn money for themselves or the charity in a cue-outcome learning task. Participants performed 40 trials (2 blocks); the first half was practice trials (block 1), and the second half was the actual trials (block 2). The practice and the actual trials were randomly presented, and each condition (i.e., the self-interest outcome cue and the other-interest outcome cue) was repeated 10 times in each block. Participants could only earn coins for themselves and the charity in the actual task.

The trial procedure was as follows (see Figure 1, panel B): A grey square appeared for 1-3 seconds (random time interval), then one of two cues (e.g., a 'star') appeared for 1 second. Like in the instrumental phase, participants could earn 10 cents for themselves when they saw a 'star' and 10 cents for charity when they saw a 'moon' (the particular S-O mapping was counterbalanced across participants). To encourage participants to process the outcome information carefully, they were asked to speak out '10 for ME' or '10 for NETS' when they saw the corresponding cues. The picture of the self-interest or other-interest outcomes ('ME' piggy bank or the 'NETS' piggy bank) was presented for 1 second. Note that while naming rewards in this task could be regarded as partly instrumental, this vocal behavior was not instrumental in obtaining the reward (participants simply had to comply with the instructions). The experimenter took notes on whether they spoke out the correct outcome in response to the cues.

Like in the instrumental learning phase, participants did not know how many trials they had to do and how many they had executed correctly. After the task, they were told how much money they had earned. We again decided to give all participants the same amount of extra money: €2 (€1 for themselves and €1 for the Against Malaria Foundation). Actual earnings thus were independent of performance. Accordingly, in total, participants earned an additional €4 for performing the Instrumental and Pavlovian task (i.e., €2 for the participant and €2 for the charity).

Test phase. In this phase, participants were informed that they could not further earn money. They were asked to respond as quickly and accurately as possible with the left or right keypress in a series of response time trials. The trial procedure of the speeded response task was taken from Qin et al. (2021) and looked as follows (see Figure 1, panel C): Each trial started with a grey square, followed by one of the three cues ('star' or 'moon' or' cloud') which appearing inside the grey square after a 1-3 seconds (randomized time-interval). After 100ms, a colored frame appeared on the computer screen surrounding the grey square, thus prompting participants to press the left or right key (counterbalanced). The Pavlovian cue remained on the screen until a response was given.

In the test phase, the cues ('star' and 'moon') that were learned to be associated with self-interest versus other-interest outcomes (or vice versa) were combined with the responses (pressing 's' and 'k' keys) that were also learned to be associated with self-interest versus other-interest outcomes. To iterate, then, a cue-based facilitation effect emerges when the self-interest cue speeds up the self-interest response, while such a speed-up effect is not expected for other-interest responses that are preceded by other-interest cues. A third neutral cue (e.g., a 'cloud') served as a baseline condition. This cue was not learned to be associated with any of the outcomes, thus allowing us to check for response time differences between self-interest and other-interest responses that are independent of Pavlovian cues. There were 120 trials (4 blocks) in total. The trials were randomly presented, and each condition was repeated 5 times in each block.

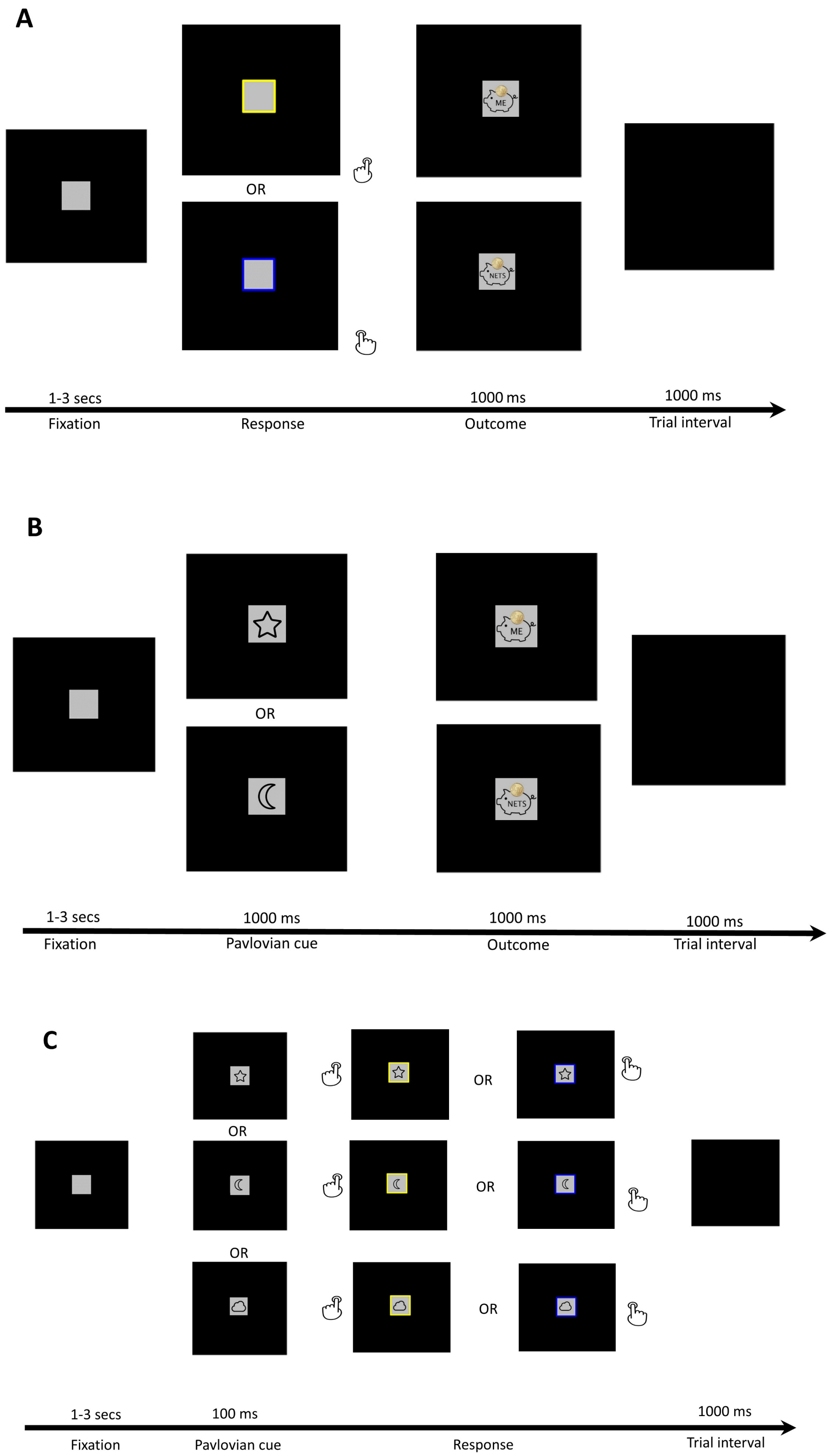

Figure 1. Flowchart of the correct response in Instrumental learning (A), Pavlovian learning (B), Test phase (C)

After the experiment, participants were thanked and received €6 (€2 for showing up and €4 for their performance in the instrumental and Pavlovian learning phases). Participants received this amount in 50 cents, €1, and €2 coins and were told they could donate their money to the Against Malaria Foundation if they wished to do so. A donation box was placed in the experiment room, which had not been visible to the participant during the experiment. To prevent social pressure from the experimenter's presence, the experimenter left the room for 20-30 seconds, during which participants could decide to either keep €6 for themselves or donate some (or all) of it. In total, participants donated €61 to the Against Malaria Foundation, which accounted for 63,5% of the initially reserved amount for donation according to the earnings in the learning phases (i.e., 48 participants * €2 for charity = €96). We donated the €61 on behalf of the participants to the Malaria Foundation.

Data preparation and analyses

We trimmed the RT data of the correct responses in the test phase for outliers (Lachaud & Renaud, 2011) and removed data points that were 3 *SD* slower or faster than that of the participant's mean RTs (4.2% of the RTs). We did the trimming because it is typically applied for analyses of stimulus-response compatibility effects (e.g., Theeuwes et al., 2014), and here we followed the same trimming procedure as in the previous research (Qin et al., 2021). Since the RT and accuracy data were not normally distributed, we performed a reciprocal transformation (i.e., 1/x) to normalize the distributions (for details of the normality test of the two experiments, see the supplemental materials, Appendix B), and we used the transformed data for further tests[1].

Considering that the conventional 2*3 repeated measures ANOVA may not capture the predicted pattern for RT, we performed a planned contrast to the RT difference in three cue conditions 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). Typically, participants should respond more readily when the cue and the response predict the same valuable outcome. Accordingly, if representing the outcome (10 cents) from a self-interest (vs. other-interest) point of view enhanced the subjective

[1] Although we used transformed data to feed the analysis, for clarifying the predicted pattern, figures of the RTs and the accuracies in both experiments were presented with untransformed data.

value of the outcome, then the cue-based facilitation effect should mainly occur in the self-interest outcome condition. This means that the RT difference between the self-interest and other-interest response should be larger in the self-interest cue condition compared to the neutral cue and the other-interest outcome cue condition. Because the other-interest representation is expected not to enhance the value of the outcome, the responses in the neutral and other-interest cue conditions will not differ.

To test this, we subjected the RT differences (self-interest minus other-interest responses) to a repeated ANOVA with neutral, self-interest, and other interest cues as a within-subject factor. Note that a negative RT difference score represents a facilitation effect for responses that lead to self-interest outcomes, and a positive one represents a facilitation effect for responses that lead to other-interest outcomes. We tested these effects according to the following contrast: +1 for the RT difference in the neutral cue condition, -2 for the RT difference in the self-interest outcome cue condition, and +1 for the RT difference in the other-interest outcome cue condition. We used the same approach as the analysis of RTs for the accuracy data analysis but reversed the contrast coding weight because participants should respond more accurately when the cue shares the identical outcome representation with the response. Note that a positive accuracy difference score represents more correct responses towards self-interest outcomes, and a negative one indicates more correct responses that lead to other-interest outcomes.

Results

Instrumental learning phase

The results of the instrumental learning phase indicate that no difference was found on RTs (t (46) = 0.76, p = .449), but the test on accuracy (t (46) = 3.15, p = .003, $Cohen'd_z$ = 0.46 [0.158; 0.766]) indicates that participants responded more accurately on the other-interest response than the self-interest response in the instrumental training phase.

Reaction times in the test phase

The pattern of reaction time difference is presented in Figure 2. The planned contrast was significant (F (1, 46) = 5.82, p = .020, η_p^2 = .11 [0.010; 0.267]). In line with predictions, the RT difference score between the self-interest outcome and other-interest outcome responses is larger and negative in the self-interest cue condition compared to the other two conditions. Furthermore, the RT difference scores did not seem to differ between the neutral and other-interest cue conditions.

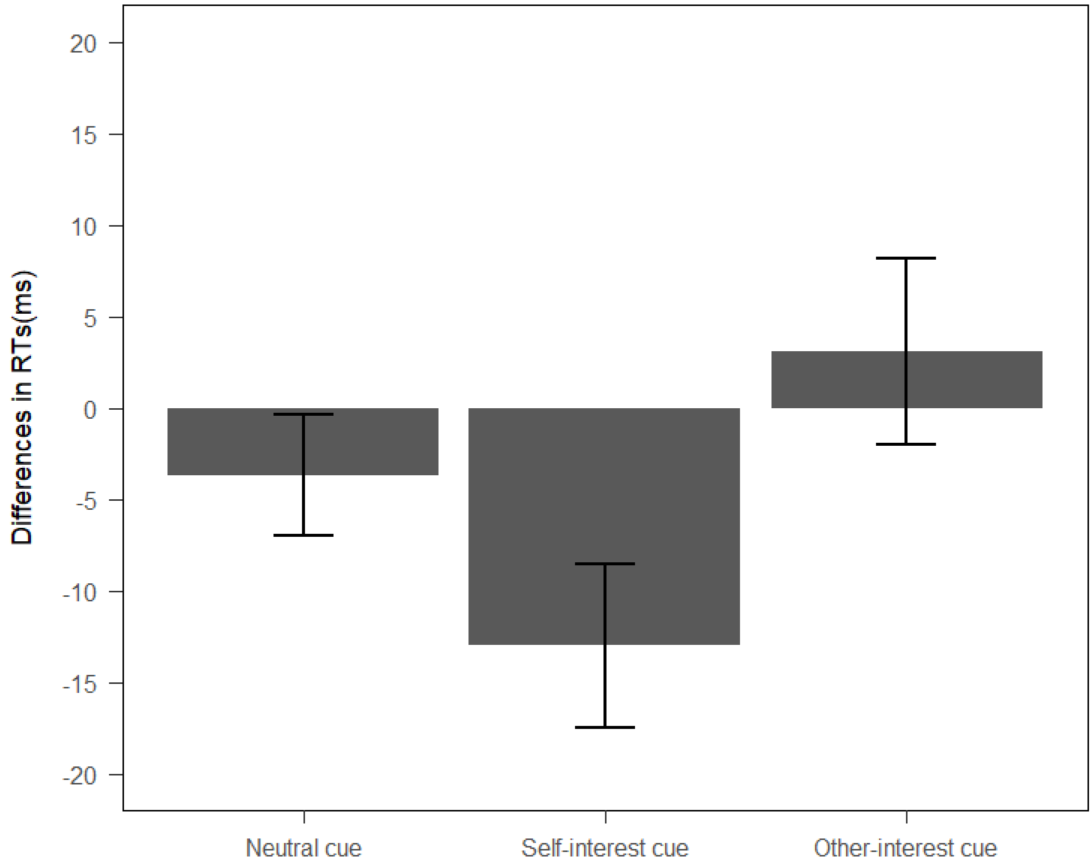

Figure 2. Experiment 1 RT difference in three cue conditions (Error bars represent one standard error). Note: A negative score represents faster self-interest responses, and a positive score represents faster other-interest responses

Accuracy

The planned contrast did not yield the predicted pattern for accuracy (F (1, 46) = 1.04, p = .313). Figure 3 presents the means of the accuracy scores in each cell of the design. Please note that if anything, the pattern of accuracy shows that participants responded more accurately to the self-interest response (vs. other-interest response) when encountering the high-value outcome cue. This suggested that the RTs effect cannot be easily explained by a speed-accuracy trade-off.

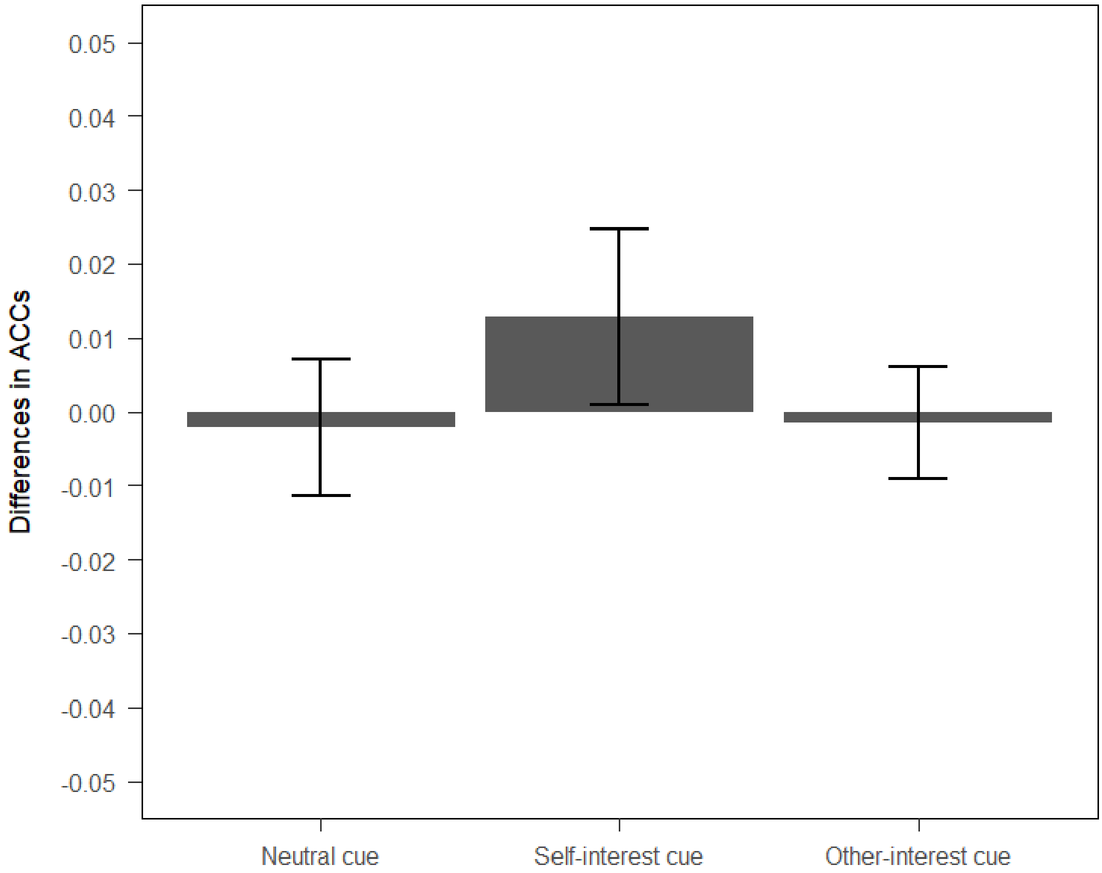

Figure 3. Experiment 1 accuracy difference in the three cue conditions of the test phase (Error bars represent one standard error). Note: A positive score represents more accurate self-interest responses, and a negative score indicates more accurate other-interest responses

Discussion

Experiment 1 showed that the same monetary reward caused a cue-based facilitation effect when that reward was earned for oneself rather than others. Considering that an effect follows from a value-based account, according to which PIT is sensitive to the value of the outcome, our findings suggest that representing the collection of 10 Euro cents in terms of being instrumental for oneself enhances the subjective value and motivation to attain it. Circumstantial evidence for this comes from the donation amount at the end of the experiment, showing that participants only paid a fraction of what they had earned in the two learning tasks. Such behavior is in line with the rich tradition of research showing that self-interest is a powerful motive for human behavior associated with personal gains (Mansbridge, 1990; Stroebe & Frey, 1982; Van Lange et al., 2007).

Our findings from Experiment 1 also show that a cue-based facilitation effect did not emerge when participants represented the behavior of earning coins in terms of donating them to the Against Malaria Foundation. From a community point of view, it would be helpful if PIT is also sensitive to behavior directed at other-interest outcomes. Research suggests that individuals can prioritize the interests of others (Dal Bó & Fréchette, 2011; Rand et al., 2012; Rand & Nowak, 2013). However, it is yet unclear why the other-relevance framing did not produce a PIT effect, as is revealed by the observation that the RTs for the neutral cue and other-interest outcome cue did not differ.

It is important to note that, in the current task, the other-interest outcome was specifically targeted at the Against Malaria Foundation, whereas the self-interest outcome could be used for any self-interested cause that participants had in mind. In other words, participants had no freedom of choice for utilizing the other-interest (vs. self-interest) outcome. Choice freedom is essential to intentional action (Antusch et al., 2021) and a strong internal motivator for behavior (Deci & Ryan, 2000). No choice freedom may have caused participants to consider the other-interest outcome less valuable compared to the self-interest outcome, thus causing the cues related to other-interest to evoke less of a facilitation effect, which is in line with the outcome value-based PIT effect (Qin et al., 2021). Accordingly, if choice freedom is central to cue-based facilitation effects of self-interest goals, then adding such freedom might also render the effect sensitive to the value of other-interest goals. We designed a second experiment to explore this further.

Experiment 2

In Experiment 2, we did not specify which charitable fund one could donate to but offered participants the opportunity to select one themselves. This way, the other-interest outcome would share the same characteristic of freely spending the earned money as the self-interest outcome in one single context, thus inducing a fairer comparison in terms of value between the two outcomes. Based on the reasoning about the choice of freedom addressed above, we expected that the cue-based facilitation effect should be observed for both self-interest and other-interest outcomes, such that self-interest cues and other-interest cues speed up self-interest responses and other-interest responses, respectively.

Method

Participants and design

We increased the sample size to obtain a more sensitive measure for detecting a cue-based facilitation effect following the findings of Experiment 1. We recruited sixty participants (mean age 23.43 (*SD* = 3.76); 45 females). Data from two participants were excluded from the analysis: one participant indicated having already participated in Experiment 1, and one participant had excessively low accuracy (< 3 *SD* from sample mean). The remaining 58 participants participated in the experiment with a 2 (Response outcome: self-interest vs. other-interest) * 3 (cue outcome: neutral vs. self-interest vs. other-interest) repeated measures design. Participants received a show-up fee of €2 and could earn €2 extra for themselves and €2 extra for the charity.

Apparatus and materials

The materials used in Experiment 2 are the same as in Experiment 1 except for the framing of the outcomes. The self-interest and other-interest outcomes that appeared in the learning phases were depicted by a full-color image of a 10-cent euro coin dropping in a piggy bank with either the word 'ME' (representing self-interest outcomes) or 'FUND' (representing other-interest outcomes) printed on it, respectively. The latter word was used to refer to the possibility of spending the money at any charitable fund one likes.

Procedure

The procedure was the same as in Experiment 1, except for the instructions regarding the charity. Before the experiment started, participants were told that they could earn extra money for themselves and for a charitable fund that they could choose themselves at the end of the experiment. After the experiment, they learned the details of three available charities to which they could select to donate their money. Apart from the Against Malaria Foundation, participants could also select the Give Directly Foundation or the Global Alliance for Improved Nutrition (GAIN): Salt Iodization Program to donate the money. All these three charities welcome small (i.e., € 2) donations (see the supplemental materials, Appendix B for complete information about the charity provided to participants). Participants could donate any amount of their earned money by putting coins inside an envelope labeled with the charity's name. The experimenter then left the cubicle. After the donation, the experimenter entered the cubicle and asked participants how they would spend the money earned for themselves to explore the idiosyncratic representation of the self-interest outcomes. The experimenter noted their answer. Finally, participants were debriefed. In total, participants donated €145.5 to the charities, which accounted for 121.3% of the initially reserved amount for donation according to the earnings in the learning phases (i.e., 60 participants * €2 for charity = €120).

Data preparation and analyses

Like in Experiment 1, we trimmed the RT data of the correct responses in the test phase (Lachaud & Renaud, 2011) by removing the RTs that were slower or faster than 3 *SD* of the participant's mean from analyses (4.0% of the RT data). We also did the reciprocal transformation to the remaining RTs and the accuracies, and we followed the same data analysis strategies as in Experiment 1. We predicted cue-based facilitation effects for both self-interest and other-interest outcome conditions, and the direction of the two effects should be opposite, i.e., a negative RT difference score in the self-interest outcome cue condition and a positive RT difference score in the other-interest outcome cue condition. Therefore, the coding for the contrast of RT difference was defined as follows: 0 for the RT difference (self minus other) in the neutral cue condition, -1 for the RT difference (self minus other) in the self-interest outcome cue condition, +1 for the RT difference (self minus other) in the other-interest outcome cue condition. The RT differences were subjected to a repeated ANOVA testing the contrast for the neutral, self-interest, and other interest cues as a within-subject factor. For the analysis of accuracy difference, we reversed the contrast coding weight because participants should respond more accurately when the cue shares the identical outcome representation with the response.

Results

Instrumental learning phase

The results indicate that no difference was found in RTs (t (57) = 0.21, p = .835) and accuracy (t (57) = -0.76, p = .449) in the instrumental training phase.

Reaction times

The pattern of RT difference is presented in Figure 4. The planned contrast was significant (F (1, 57) = 5.91, p = .018, η_p^2= .09 [0.009; 0.228]). Although the neutral cue seemed to facilitate the self-interest response to some extent, the RT differences were in line with the predicted pattern: The self-interest outcome cue and other-interest outcome cues caused participants to be faster to respond with the corresponding outcome response, and their directions are opposite.

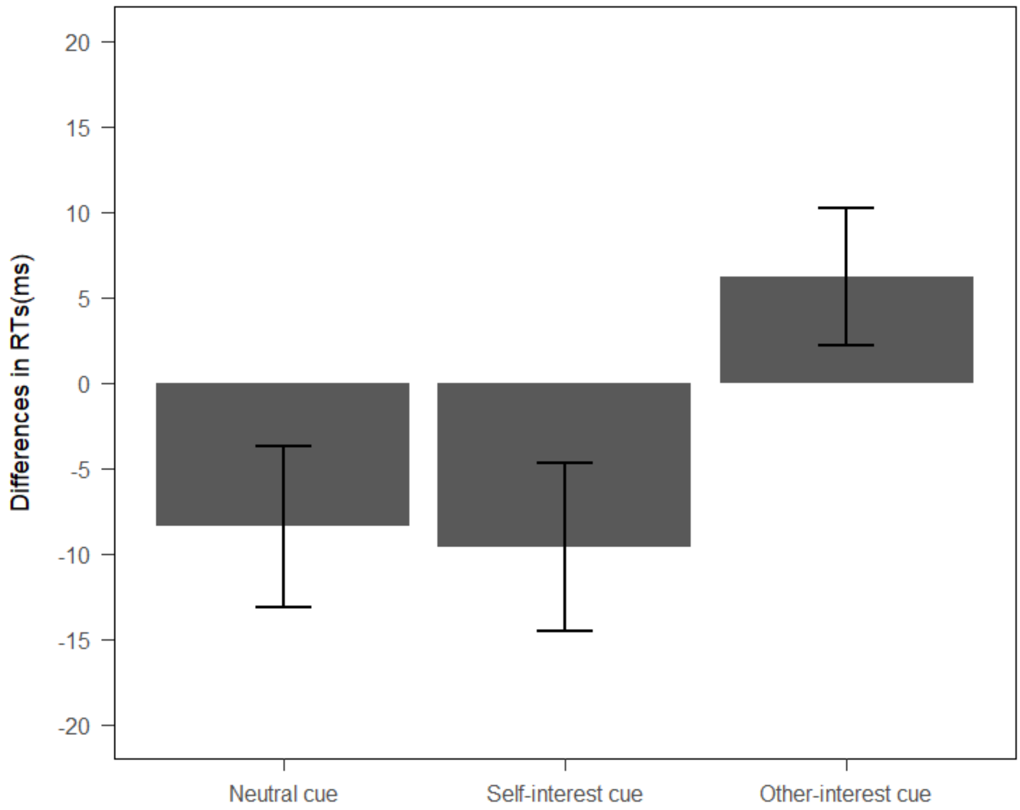

Figure 4. Experiment 2 RT difference in the three cue conditions (Error bars represent one standard error). Note: A negative score represents faster self-interest responses, and a positive score represents faster other-interest responses

Accuracy

The pattern of accuracy difference is presented in Figure 5. The planned contrast was not significant (F (1, 57) = 0.408, p = .526).

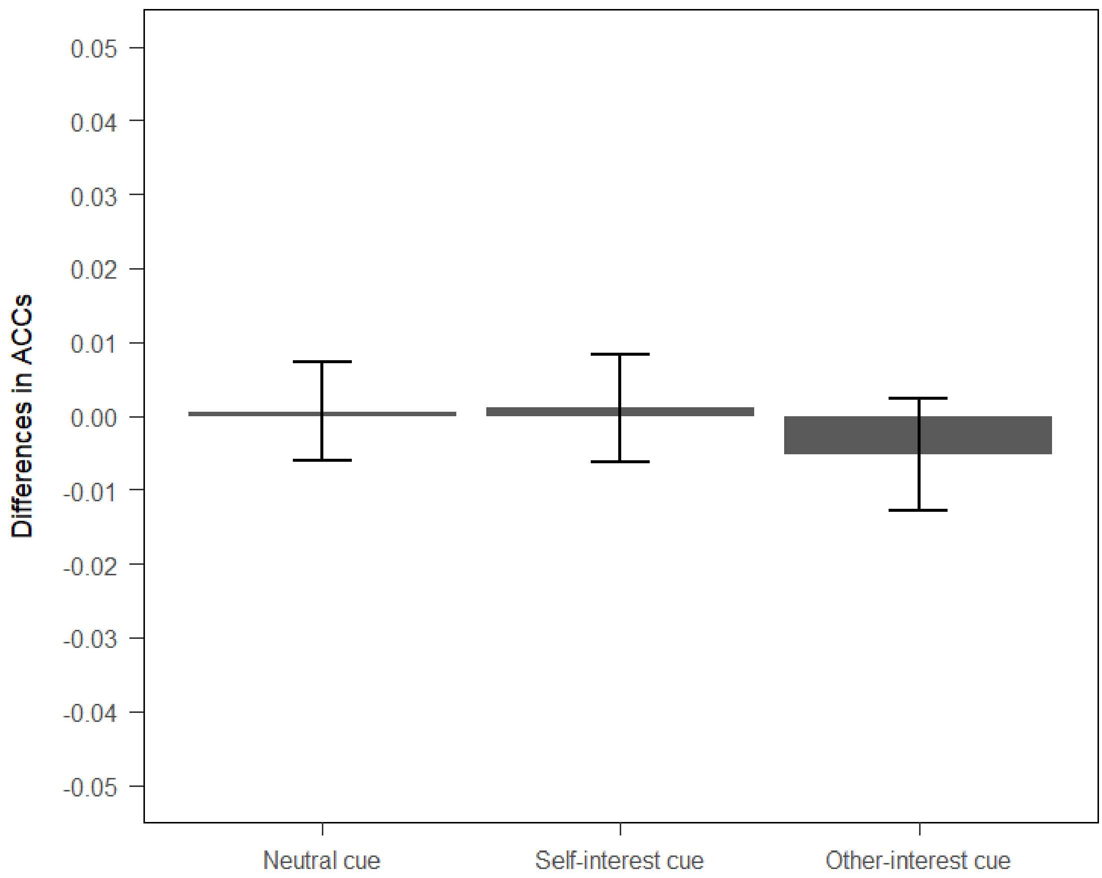

Figure 5. Experiment 2 accuracy difference in the three cue conditions (Error bars represent one standard error). Note: A positive score represents more accurate self-interest responses, and a negative score indicates more accurate other-interest responses

Discussion

In Experiment 2, we found evidence for a cue-based facilitation effect for self-interest outcomes as well as for other-interest outcomes. These findings differ considerably from those in Experiment 1, in which this effect only seemed to be present for the self-interest outcomes. Compared to the findings of Experiment 1, the other-interest outcome cue reversed the speed of executing other-interest responses. A clear difference between the two experiments concerns participants' ability to decide how to spend the money. Whereas Experiment 1 enabled participants to freely select an action for the self-interest outcome but not for the other-interest outcome, in Experiment 2, participants could freely choose how to spend the money in both outcomes. This pattern suggests that giving participants choice freedom over actions renders the other-interest outcome desirable as well in the task at hand. Circumstantial evidence for the relative importance of spending money on other-interest outcomes can be derived from the donation amount at the end of the experiment, showing that participants paid more to a self-chosen donation fund than they earned for themselves.

It should be noted that because we compared the cue-based facilitation effect of self-interest and other-interest outcome cues with a neutral cue condition, the results of Experiment 2 seem to show that the self-interest outcome cue only slightly increased the speed of self-interest actions compared to the neutral cue condition. One possibility could be that participants were generally faster in initiating the self-interest (compared to other-interest) responses, thus reducing the differences between the baseline and the self-interest cue condition. This observation resonates with the wealth of studies on the effects of self vs. other representations in action fluency and action control (Moore, 2016; Ruys & Aarts, 2010; Sebanz et al., 2003). Alternatively, participants might have explicitly compared the self-interest outcome with the other-interest outcome and concluded that the self-interest outcome is less valuable in the social context at hand. Importantly, whereas we do not know whether this process especially occurred in Experiment 2, the data still yielded the planned contrast effect on RT, revealing that self-interest and other-interest responses were both facilitated by the respective self-interest and other-interest outcome related Pavlovian cues.

General Discussion

The present study was set out to examine whether social goals and resulting actions can be controlled by environmental cues. People are highly motivated to seek rewards for self-interest purposes, while such motivation is commonly less strong when seeking rewards in the interest of others. By building on the PIT paradigm, we examined whether the subjective value of self- and other-interest outcomes can change the strength of the PIT effect. Employing a cue-based forced-choice response time task, the results of Experiment 1 indicated that cues associated with self-interest (vs. other-interest) monetary outcomes caused participants to speed up instrumental action to attain the pro-self goal, even though participants had no direct sensorimotor experiences as to performing the action in response to the cues. This concurs with a goal-directed process that has been previously addressed in PIT studies (Mahlberg et al., 2021).

Furthermore, while Experiment 1 showed a cue-based effect on pro-self goal pursuit but not on pro-social goal pursuit, we reasoned that such difference occurred because of the difference in freedom to spend the earned money: Spending the money on oneself the way one like vs. spending the money only at donating to one charity (here the Against Malaria Foundation). As has been argued before, money is an all-purpose commodity that allows people to achieve several goals (Bijleveld & Aarts, 2014). From this all-purpose perspective, our findings suggest that earning money for other-interest outcomes can be cue-based when people learn to have the freedom to use the monetary reward. Interestingly, research on consumer behavior indicates that people prefer products that are considered to have more freedom (e.g., more functions) and judge them to be more worthy (Brannon & Soltwisch, 2017; Ozcan & Sheinin, 2015). Considering the results from this view, the current study indicates that having a say in how to spend money on others renders pro-social goals more valuable, perhaps even more valuable in comparison with pro-self goals. This inference is further supported by the amount of money participants donated. In Experiment 2, they donated more coins than required, suggesting that they were more motivated to achieve the pro-social goal than the pro-self goal.

The present findings also speak to previous research on concept activation effects on behavior, which relies on individual pre-existing knowledge about the action-relevant meaning of concepts (Herr, 1986; Loersch & Payne, 2012; Weingarten et al., 2016). This research argues when stimuli (such as words or pictures) are associated with a goal concept (compete, help) that is mentally represented as an outcome of action in a person's mind, these stimuli can trigger the goal and resulting action. Whereas this research may indicate that environmental cues can trigger action through activating social goals, this research does not rule out whether the stimulus evokes action directly, thus not excluding an S-R habit account. For instance, exposure to the word "competing" or "helping" might evoke motor activity available in a person's behavioral repertoire, but this does not necessarily mean that the action is driven by pro-self or pro-social goals directed at attaining self- or other-interest outcomes. Here we experimentally investigated and showed how the transfer from a Pavlovian cue to Instrumental action occurs as part of their shared overlap with the self- or other-interest outcome attached to both. Thus, the route from cue to action is assumed to depend on the representation of the pro-self or prosocial goal that mentally lumps the cue and action together. The present findings, then, show that PIT provides an important additional test to examine whether cue-based behavior is mediated by the representation of human goals, such as pro-self and pro-social goals that were examined here.

Although our findings suggest that the PIT forced-choice task is a promising tool to assess the occurrence of automatic social goal pursuit, a few important notes are in place. First, our approach differs substantially from the common approach in PIT research. In most PIT studies with human subjects, different instrumental responses (e.g., pressing a left or right button) and Pavlovian cues (e.g., a blue or red light) are linked to different outcomes (e.g., obtaining popcorn or crisps). Thus, outcomes contain not only the perceptual properties of the outcome (e.g., size, color, taste) but also the motivation derived from the value of the outcome (Watson et al., 2018). Value-based specific PIT effects are then tested by devaluing one of the outcomes (e.g., making popcorn taste unpleasant) or by comparing two outcomes of different values (popcorn vs. tomato; monetary reward of 10 cents or 50 cents). In the present study, we used one single rewarding outcome (a 10 Eurocent coin) and reasoned that, in principle, attaining this reward has higher subjective value being framed as a self-interest (compared to other-interest) outcome. However, although the established PIT effect supports this idea, we did not devalue the outcome or measure the subjective value directly. This shortcoming is particularly an issue in Experiment 2, in which we expected that both the pro-self and pro-social goals would be triggered by the associated Pavlovian cues. The fact that only the pro-social goal showed PIT effects suggests that the self-interest outcome was devalued in the task at hand. Furthermore, the findings of Experiment 2 also show that the neutral cue (baseline) condition resembles the effect of the self-interest cue condition, suggesting that the absence of the pro-self goal effect could be due to changes in the baseline condition (see discussion of Experiment 2).

Furthermore, the typical PIT methodology for studying human behavior is to test the effects of cues in free-choice settings that target decision-making processes. Although Pavlovian cues have the potential to evoke goal-directed decision-making, earlier, we argued that the decision responses are open to disturbances from free choice and task-strategic processing. We aimed to circumvent this issue by designing a PIT test that employs a forced-choice speeded task (see also Qin et al., 2021; Watson et al., 2016). Forced choice tasks provide the opportunity to test the influence of cues by creating response facilitation situations, as is typically done in response priming (Kiesel et al., 2007) or Simon tasks (e.g., Simon & Acosta, 1982). The logic is simple: When a cue triggers a response that one is instructed to perform, a response speed-up arises. Thus, integrating PIT research with forced-choice speeded tasks allows us to test how specific responses that are instrumental in attaining specific outcomes (low vs. high-value outcome) are evoked by the Pavlovian cues associated with these outcomes. Importantly, a limitation of such a task is that one can only look at the initiation of actions and not the motivation to engage in them. Hence, a test methodology that relies on the speed of responding could be further developed, including a measure of motivational strength, such as investing effort in action performance once action initiation takes place. In fact, original studies on PIT with animals considered (albeit implicitly or explicitly) the degree of motivational strength as an essential part of the PIT test, as being operationalized by action intensity and persistency in the presence of Pavlovian cues (Berridge, 2000; Dickinson & Balleine, 1994).

Finally, the current findings indicate that cue-based goal-directed behavior is sensitive to the social meaning of rewarding outcomes at stake. In so doing, our findings may stimulate PIT research to take a closer look at the role of social cognition. For example, an essential root of other-interest behavior is the human capacity to empathize and understand other people's mind (Decety & Jackson, 2004; Frith & Frith, 2005; Iacoboni, 2009; Leslie et al., 2004). People care about others and are empathic in predicting and emotionally evaluating the consequences of their actions for others. The PIT paradigm may be helpful to further our understanding of the human nature of social behavior and to generate testable hypotheses relevant to how other-interest outcomes are learned, represented, and expressed in the presence of environmental cues. An intriguing and important direction for future research might be testing whether and how the effects of choice freedom and empathy interact in shaping other-interest behavior as a result of PIT because, under such conditions, people might be able to freely put their own concerns aside to help others in the way they like.

CHAPTER
4

Chapter 4:

How the environment evokes actions that lead to different goals: The role of object multi-functionality in Pavlovian-to-instrumental transfer

This chapter is based on: Qin, K., Marien, H., Custers, R., & Aarts, H. (2023b). How the environment evokes actions that lead to different goals: The role of object multi-functionality in Pavlovian-to-instrumental transfer. *Current Psychology.* https://doi.org/10.1007/s12144-023-04612-2

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KQ: Conceptualization, Methodology, Investigation, Writing-Original-Draft, Writing-Review & Editing, Visualization. **HM**: Conceptualization, Methodology, Writing-Review & Editing, Supervision. **RC**: Conceptualization, Writing-Review & Editing. **HA**: Conceptualization, Methodology, Writing-Review & Editing, Project administration, Supervision.

Abstract

Research shows that stimuli in the environment can trigger behavior via the activation of goal representations. This process can be tested in the Pavlovian-to-Instrumental Transfer (PIT) paradigm, where stimuli can only affect behavior through the activation of the representation of its desired outcome (i.e., the PIT effect). Previous research has demonstrated that the PIT effect is stronger when the goal is more desirable. While this research only looked at actions that have single outcomes (e.g., obtaining a snack to satisfy appetite), in the present paper, we reason that actions that are instrumental in obtaining outcomes that are desirable in multiple ways (e.g., obtaining a snack to satisfy one's appetite, giving it to a friend, trading it for money) should produce stronger PIT effects. In two experiments, participants learned to perform left and right key presses to earn a snack, either framed as having a single function or multiple functions. Participants also learned to associate the two differently framed snacks with two cues. In a PIT test, they were required to press the keys as fast as possible upon exposure to the cues (i.e., the PIT effect). We found that cues associated with the multi-functional snack facilitated the actions that earned those snacks before, while cues associated with the single-functional snack did not facilitate such actions. We discuss these findings in the context of research on free choice and personal autonomy and how people appreciate the multi-functional nature of their goal-directed behavior in the environment.

Keywords: Environmental cues**,** goal-directed behavior, single-functional outcome, multi-functional outcome, specific Pavlovian-to-instrumental transfer, outcome value

Introduction

Human beings engage in goal-directed behavior. Engaging in goal-directed behavior relies on the ability to represent which actions lead to which desired outcomes or rewards (Dickinson & Balleine, 1994; Prinz, 1997), and to decide which action to execute in order to obtain which outcomes. Although setting a goal and anticipating the desired outcome is often regarded as the starting point for goal-directed action (Gollwitzer, 1990; Locke & Latham, 1990), it has been argued that goal-directed behaviors that are frequently selected in the same context can also be triggered by stimuli in the context that directly activate the mental representation of the goal (Custers & Aarts, 2010). Despite the empirical evidence supporting such environmental control of goal-directed behavior (Weingarten et al., 2016), strict tests of the mediating role of goals in human behavior are scarce.

Such a strict test, though, has been developed in animal research to demonstrate that animal behavior can indeed be mediated by goals. This test has become known as the specific Pavlovian-to-instrumental transfer (PIT) test (Cartoni et al., 2016; Holmes et al., 2010; Mahlberg et al., 2021). The key feature of this paradigm is that it separates the processes of instrumental conditioning (e.g., where the animal learns that behavior is instrumental in obtaining an outcome) and Pavlovian conditioning (e.g., where the animal learns that a stimulus is followed by a desired outcome). Therefore, if the stimulus triggers the instrumental behavior in a later transfer test, this effect would have to be mediated by the representation of the desired outcome. That is, as the stimulus and the behavior never occurred together in the training phase, this effect cannot be regarded as a direct effect of stimulus-response (S-R) associations (Wood & Rünger, 2016) but has to be mediated by the goal representation.

Recently, this PIT paradigm has been applied to humans as well (Cartoni et al., 2016). Usually, specific PIT tests in humans require participants to perform two responses (e.g., pressing a left or right key) that produce two desirable outcomes or rewards (e.g., obtaining chocolates or crisps) to acquire response-outcome (R-O) associations in the instrumental learning phase. Furthermore, in the Pavlovian learning phase, participants learn unique stimulus-outcome (S-O) associations between two Pavlovian stimulus cues and the two outcomes. In the transfer test, it is tested whether participants' responses are facilitated (e.g., more frequent, faster, or more accurate) when the stimulus cue and the response are associated with the same outcome, especially when the outcome that is shared by the cue and response is valuable to the person in the context at hand (Qin et al., 2021). Accordingly, the specific PIT effect can be used to demonstrate cue-based motivational control over goal-directed behavior in humans (Mahlberg et al., 2021).

In the present paper, we test an important prediction based on the notion that cues can motivate and control goal-directed behavior: If such motivational control is dependent on the value of the outcome, such control should be stronger for more valuable outcomes. While value has been successfully manipulated before (Qin et al., 2021; Qin et al., 2023a) using the monetary reward of different value (e.g., 5 vs. 50 cents coins), here we focus on a universal property of outcomes: the fact that outcomes can satisfy multiple needs or higher order goals (i.e., multifinality; Kruglanski et al., 2002). For instance, although a specific action could be regarded as producing a single outcome (e.g., obtaining a snack to satisfy one's appetite), actions can also be perceived as being instrumental in satisfying different needs or attaining multiple goals (e.g., obtaining a snack can satisfy appetite but can also serve as a present for a friend). Thus, by taking the hierarchical nature of goal-directed behavior into account (Carver & Scheier, 1981; Gallistel, 1985; Kruglanski et al., 2002; Vallacher & Wegner, 1987) and building on the notion that multi-functional objects are experienced as more valuable compared to single-functional objects (e.g., Brannon & Soltwisch, 2017; Ozcan & Sheinin, 2015), we examine whether the PIT effect is stronger when specific outcomes of actions (such as food) serve multiple outcomes.

People may find multi-functional objects more desirable than single-functional objects as multi-functionality (in comparison to single-functionality) renders behavior inherently more flexible and offers more degrees of freedom in responding to opportunities and demands posed by the social and physical environment (Bijleveld & Aarts, 2014; Kruglanski et al., 2015; Mikhalevich et al., 2017). Specifically, single-purpose objects put severe constraints on usability of the object. In contrast, multi-purpose objects allow for more choice, such as deciding when, how, and where to use the object (Zhang et al., 2022). According to the theory of self-determination, people have an innate need to act autonomously and therefore appreciate personal freedom of choice (i.e., the need for autonomy; Deci & Ryan, 1985; Ryan & Deci, 2000; Ryan & Deci, 2017). Having personal freedom of choice thus increases the desirability of goal-directed behavior and motivates people to engage in it. Single-functional objects, then, may be perceived to be less valuable than multi-functional objects because single-functionality forces the person to use the object in one way, while multi-functional objects offer more freedom.

In line with the notion of the relationship among personal freedom of choice, flexibility, and the value of objects, consumer psychology studies suggest that consumers prefer multi-functional products over single-functional products and consider multi-functional products to be more valuable (e.g., Brannon & Soltwisch, 2017; Ozcan & Sheinin, 2015). Similar effects have been found in the context of goal-means relations. Multi-final (vs. uni-final) means can attain more than one goal simultaneously. Such means or subgoals have an advantage over uni-final ones because they are considered to have greater overall value (Chun & Kruglanski, 2005; Orehek et al., 2012). The preference for multi-functional products is also reflected in consumers' purchase intentions (Arruda Filho & Brito, 2017; Han et al., 2009). For example, Arruda Filho et al. (2017) showed participants different mobile phones that either included an environmental-friendly function or not (e.g., a solar energy recharge system). They found that participants' purchase intention was stronger when the product had an additional function. Moreover, recent empirical research demonstrates that people value the freedom to choose and prefer choosing themselves over having a choice made for them (Shoval et al., 2022). Together, these studies suggest that multi-functional objects should be associated with higher perceived value than single-functional objects.

To summarize, existing studies on autonomy and consumer psychology have indicated that multi-functional outcomes should be perceived as having higher value. Given that outcome value plays an essential role in moderating the sensitivity of cue-based goal-pursuit (e.g., Qin et al., 2021), cues associated with multi-functional outcomes may benefit goal-directed behavior more in a cue-based goal-pursuit context. Hence, an important question that remains to be answered is whether cues associated with multi-functional outcomes are more effective in facilitating goal-directed behavior than cues linked with single-functional outcomes.

Testing this effect is crucial since it sheds light on how an individual’s representation of outcomes plays a role in the environmental control of goal-directed behavior. Human beings can pursue more abstract or high-level goals, and such processes can also be guided by environmental cues (also see: Qin et al., 2023a). Here we investigate this higher level of abstraction by focusing on actions that are instrumental in obtaining outcomes that are desirable in multiple ways. This examination would offer a unique test of whether complex human goal-pursuit, especially abstract or high-level goals, can be studied testing for classical learning mechanisms (e.g., FeldmanHall & Dunsmoor, 2018). This exploration could serve as a significant point of reference for future studies on connecting fundamental learning processes (e.g., R-O and S-O associations) with the pursuit of high-level goals (Custers, 2023).

We report two experiments that examine whether cues can control goal-directed behavior. Specifically, we test whether cues referring to objects presented as multi- versus single-functional evoke stronger PIT effects, which represent stronger goal-directed behavior facilitated by cues (Mahlberg et al., 2021). Specifically, we relied on the cue-based forced-choice response time PIT paradigm (Qin et al., 2021; Qin et al., 2023a) to test response facilitation upon exposure to outcome cues. First, participants were taught to press two different keys (left or right) to earn a snack they liked in the instrumental learning phase. We used one snack to manipulate the multi-functionality of the same snack without confounding the actual value or other features of different snacks. In Experiment 1, the snack was framed as serving only one single purpose on one condition. In the other condition, the snack was framed without such constraints. In Experiment 2, we further aimed to replicate Experiment 1 by explicitly addressing the role of multi-functionality in terms of perceived freedom of choice. In the Pavlovian learning phase, they learned to associate the single- or multi-functional snack with two different cues. In a final test phase, we exposed participants to the two Pavlovian cues just before executing one of the two responses. This setup allows us to test whether the PIT effect is stronger when the snack is not constrained and thus could serve multiple purposes compared to the single-functional snack cue.

Experiment 1

The purpose of the first experiment is to provide initial support for the idea that specific PIT effects mainly show up for multi-functional objects. Multi-functionality was manipulated by stressing that one of the candy bars had to be consumed directly after the experiment in the lab (single-functional condition). The other candy bar could be taken home, thus implying that participants were allowed to do with it whatever they wanted (multi-functional condition). Based on the reasoning that multi-functionality increases the perceived value of objects, we examined whether participants' responses were facilitated by Pavlovian cues associated with the multi-functional candy bar versus the cues associated with the single-functional candy bar.

Method

Participants and design

Aiming to detect a medium effect size ($\eta_p^2 = .10$, based on the previous study by Qin et al., 2021) with a power of 80%, we used 3 measurements for the 2 x 3 within-subjects design test and epsilon = 1 (Faul et al., 2007). The power analysis revealed that at least 46 participants were needed. We decided to recruit 5 more participants concerning the possible dropout. Finally, we recruited 51 undergraduate students (21 males; mean age 21.86 (*SD* = 1.80)) by posting advertisements targeting English-speaking students under the age of 40. Participants participated in the experiment where two different responses and two different cues could either be related to an object framed as single or multi-functional. This resulted in a 2 (Response outcome: single-functional object vs. multi-functional object) x 3 (Cue outcome: neutral vs. single-functional vs. multi-functional) repeated measures design. The neutral cue was used as a baseline to control for differences between the speed of single-functional object responses and multi-functional object responses. Participants received a fixed amount of €1 show-up payment. Moreover, they could earn two extra candy bars, one for consuming immediately after the experiment (single-functional outcome) and one for taking home to do anything they wanted with it (multi-functional outcome).

Apparatus and materials

The experiment was conducted in a soundproof cubicle equipped with a computer monitor (1920*1080 pixels) and a standard keyboard. MATLAB's Psychophysics Toolbox Version 3.0.10 was used to present the tasks (Brainard, 1997). At the beginning of the experiment, participants could select one snack from four candy bars (Figure 1) as their reward. A grey square (RGB 192 192 192, visual angle 6.60˚), three figures (i.e., a 'star', a 'moon', and a 'cloud' visual angle 6.60˚) and two-colored frames (i.e., yellow, RGB 255 255 0 and blue, 0 0 255 visual angles 6.86˚) appeared in the experiment. The single and multi-functional snacks were represented by a full-color image of a selected snack (visual angles 6.60˚) with the words 'NOW' and 'HOME' printed, respectively. The word 'NOW' was used to refer to the single function (consume the snack), and the word 'HOME' was used to refer to the multi-functions (take it home and do whatever they like with it).

Procedure

Upon arrival at the laboratory, participants signed the informed consent, and the experimenter told participants that this experiment aims to detect how fast people can react to visual stimuli. Before the experiment started, participants had to indicate which out of four types of candy bars they would like to earn (see Figure 1) as rewards. Specifically, they were informed that they had to collect (a non-specified number of) points to earn this reward by performing two experimental (instrumental and Pavlovian learning) tasks. This apparent progression in earning points was assumed to increase the motivation to perform well (Pierce et al., 2003; Locke & Braver, 2008).

They also learned that they could earn two of their candy bars as snacks in total, but one could be consumed immediately, and the other could be taken home so they could do whatever they like with it. We refer to this condition as the single- and multi-functional outcome, respectively.

Next, they filled out a questionnaire to check whether participants valued the multi-functional snack more than the single-functional snack. Participants responded to six items (3 items for each type of snack) to assess their liking, willingness to spend effort, and motivation to obtain the snacks. The self-report items were measured on a 5-point Likert scale (see supplemental materials, Appendix C for details). After the questionnaire, the experiment started.

The experimenter stayed in the cubicle during the entire experiment to note their performance. The experiment contains four phases: a demonstration phase, an instrumental learning phase, a Pavlovian learning phase, and a test phase.

Figure 1. snacks used as the reward outcome

Demonstration phase. During this phase, participants performed the speeded response task that was also administered during the test phase to familiarize them with the procedure of the task. Participants performed 42 randomly presented trials in total.

Instrumental learning phase. Participants learned that they earned points for obtaining the single or multi-functional snack by producing two different motor responses. Participants first practiced 20 trials (block 1), followed by 20 real trials (block 2). The trials in the practice and the actual task were randomly presented, and each condition (i.e., the single-functional snack response and the multi-functional snack response) was repeated 10 times in each block. The trial procedure is depicted in Figure 1 (panel A): Each trial started with a grey square for 1-3 seconds (random time interval), then a yellow or blue frame indicated to press the left or right key. Participants could earn points for getting the single-functional snack by correctly pressing the (left) 's' key (yellow frame) and the multi-functional snack by correctly pressing the (right) 'k' key (blue frame); colored frames were counterbalanced across participants. After a correct keypress, the single-functional or multi-functional outcome was presented for 1 second (i.e., a picture of the single-functional snack titled 'NOW' or the multi-functional snack titled 'HOME'), meaning participants earned points for the single-functional or multi-functional snack. If participants made a wrong keypress, they saw a red cross. The snack picture displayed the word 'NOW or 'HOME to support participants in keeping the single vs. multi-functional outcome in mind. To encourage participants to process the outcome information carefully, they had to speak out 'snack for now' or 'snack for home' upon seeing the snack (Qin et al., 2021; Qin et al., 2023a, for a similar procedure). The experimenter noted whether participants spoke out the correct outcome at the moment.

Participants did not know in advance how many points they could earn. They also did not know how many trials they had executed and how many trials they had to do. After the task, all participants were informed that they performed well. We decided to inform all participants that they earned 200 points (suggesting they made progress in obtaining the snacks). Actual earnings thus were independent of the keypress performance.

Pavlovian learning phase. In this phase, participants learned that they could earn points for the single and multi-functional snacks in a cue–outcome learning task. Participants performed 40 trials (2 blocks); the first half was practice trials (block 1), and the second half was the actual trials (block 2). The practice and the actual trials were randomly presented, and each condition (i.e., the single-functional snack cue and the multi-functional snack cue) was repeated 10 times in each block.

The trial procedure was as follows (see Figure 2, panel B): A grey square appeared for 1-3 seconds (random time interval), then one of two cues (e.g., a 'star') appeared for 1 second. Participants earned points for the single-functional snack by speaking out 'snack for now' when they saw a 'star' and points for the multi-functional snack by speaking out 'snacks for home' when they saw a 'moon' (the particular S-O mapping was counterbalanced across participants). The experimenter took notes on whether they spoke out the correct outcome in response to the cues. The picture of the single-functional and multi-functional snack (NOW snack or HOME snack) was presented when they spoke out the corresponding outcome. Participants only earned points for the actual task.

Like in the instrumental learning phase, participants did not know how many points they could earn, how many trials they had executed, and how many trials they had to do in the actual task. After the task, they were told how many points they had earned. We again decided to give all participants the number of points. Hence, they were informed that they performed well and earned 200 points. Actual earnings points thus were independent of performance. Accordingly, all participants learned that they had enough points to receive both the single and multi-functional snacks in both tasks.

Test phase. Participants were informed that they could not further earn points in this phase. They were asked to respond as quickly and accurately as possible with the left or right keypress in a series of trials. The trial procedure of the speeded response task was taken from Qin et al. (2021) and looked as follows (see Figure 2, panel C): Each trial started with a grey square, followed by one of the three cues ('star' or 'moon' or' cloud') which appearing inside the grey square after a 1-3 seconds (randomized time interval). After 100ms, a colored frame appeared on the computer screen surrounding the grey square, thus prompting participants to press the left or right key (counterbalanced). The Pavlovian cue remained on the screen until a response was given.

In the test phase, the cues ('star' and 'moon') that were learned to be associated with single-functional versus multi-functional snacks (or vice versa) were combined with the responses (pressing 's' and 'k' keys) that were also learned to be associated with single-functional versus multi-functional snacks. To iterate, then, a value-based specific PIT effect emerges when the multi-functional snack cue speeds up the multi-functional snack response, while such a speed-up effect is not expected for single-functional snack responses that are preceded by single-functional snack cues. A third neutral cue (e.g., a 'cloud') served as a baseline condition. This cue was not learned to be associated with any of the outcomes, thus allowing us to check for response time differences between single-functional and multi-functional snack responses that are independent of PIT effects. There were 120 trials (4 blocks) in total. The trials were randomly presented, and each condition was repeated 5 times in each block.

After the test phase, all participants received the two candy bars, one they had to consume immediately and one they could take home. Participants consumed the former when they received it and took the latter with them.

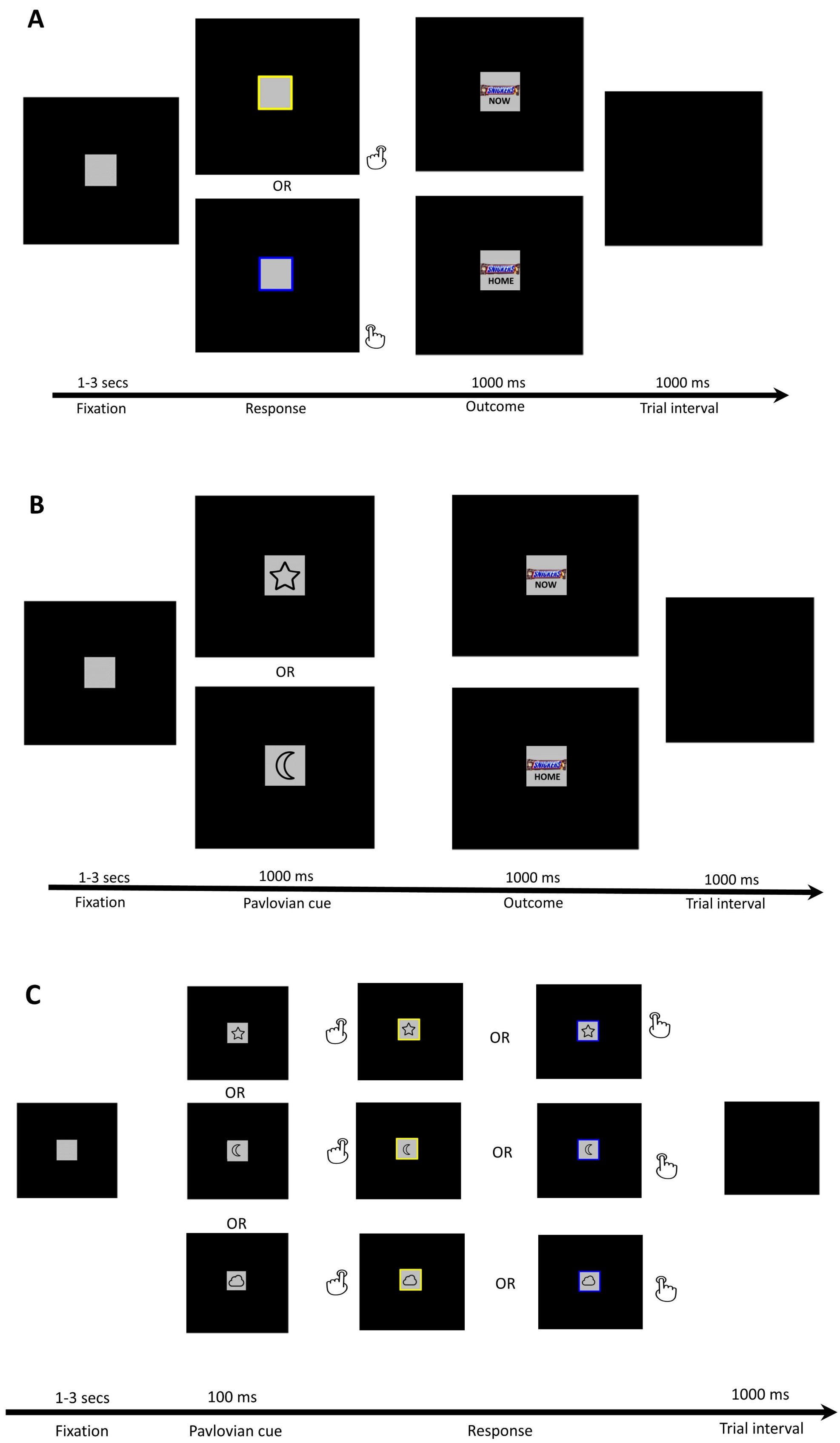

Figure 2. Flowchart of the correct response in Instrumental learning phase (A), Pavlovian learning phase (B), Test phase (C)

Data preparation and analyses

We trimmed the RT data of correct responses in the test phase for outliers as in previous studies (Qin et al., 2021; Qin et al., 2023a). Specifically, RTs from incorrect responses and RTs that were slower or faster than 3 *SD* of the participants' mean were removed from analyses (4.6% of the RT data). Since the RT and accuracy data were not normally distributed, we performed a reciprocal transformation (i.e., 1/x) to normalize the distributions (for details, see the supplemental materials, Appendix C). We used the transformed data for further tests[1].

We analyzed the RTs data as in previous studies (Qin et al., 2021, Qin et al., 2023a). We performed a planned contrast to the RT difference in three cue conditions 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). Participants should respond more readily when the cue and the response predict the same desirable outcome in specific PIT effects. Accordingly, if representing the snack from a multi-functional (vs. single-functional) point of view enhanced the subjective value of the snack, then the PIT effect should mainly occur in the multi-functional outcome condition. This means that the RT difference between the multi-functional and single-functional outcome response should be larger in the multi-functional cue condition compared to the RT difference in the neutral cue and the single-functional outcome cue condition. Since the single-functional representation is expected not to enhance the value of the outcome when compared to the multi-functional representation, the responses to the neutral and single-functional cues will not differ.

To test this, we subjected the RT differences (single-functional outcome responses minus multi-functional outcome responses) to a repeated ANOVA with neutral, single-functional, and multi-functional cues as a within-subject factor. Note that a negative RT difference represents a facilitation effect for responses that lead to single-functional outcomes, and a positive one represents a facilitation effect for responses that lead to multi-functional outcomes. We tested effects according to the following contrast: -1 for the RT difference in the neutral cue condition, -1 for the RT difference in the single-outcome cue condition, and +2 for the RT difference in the multi-functional outcome cue condition. Compared to the neutral cue, then, the multi-

[1] Although we used transformed data to feed the analysis, for clarifying the predicted pattern, figures of the RTs and the accuracies in both experiments were presented with untransformed data.

functional outcome cue should speed up the multi-functional (vs. single-functional) outcome response, while the single-functional outcome cue does not (or to a lesser extent) speed up the single-functional (vs. multi-functional) outcome response. The same approach was also applied to the accuracy data, but the contrast coding weight was reversed because participants should respond more accurately when the cue shares the identical outcome representation with the response. Note that a positive accuracy difference score represents more accurate responses toward single-functional outcomes, and a negative one indicates more accurate responses that lead to multi-functional outcomes.

To analyze the questionnaire data, we conducted three t-tests (2-tailed) to compare the self-report scores of liking, willingness to spend effort, and motivation to obtain the single-functional and multi-functional snacks.

Results

Reaction times

The pattern of reaction time differences in each cue condition is presented in Figure 3. The planned contrast was significant (F (1, 50) = 5.94, p = .018, η_p^2 = .11 [0.010; 0.253]). In line with predictions, the RT difference score between the multi-functional and single-functional outcome responses is positive in the multi-functional cue condition compared to the other two conditions, indicating that multi-functional cues facilitated multi-functional outcome responses. Furthermore, whereas the RT difference score between the multi-functional and single-functional outcome responses is negative in the single-functional cue condition (suggesting that single-functional cues facilitated single-functional outcome responses), the RT difference does not seem to differ between the neutral and single-functional cue conditions.

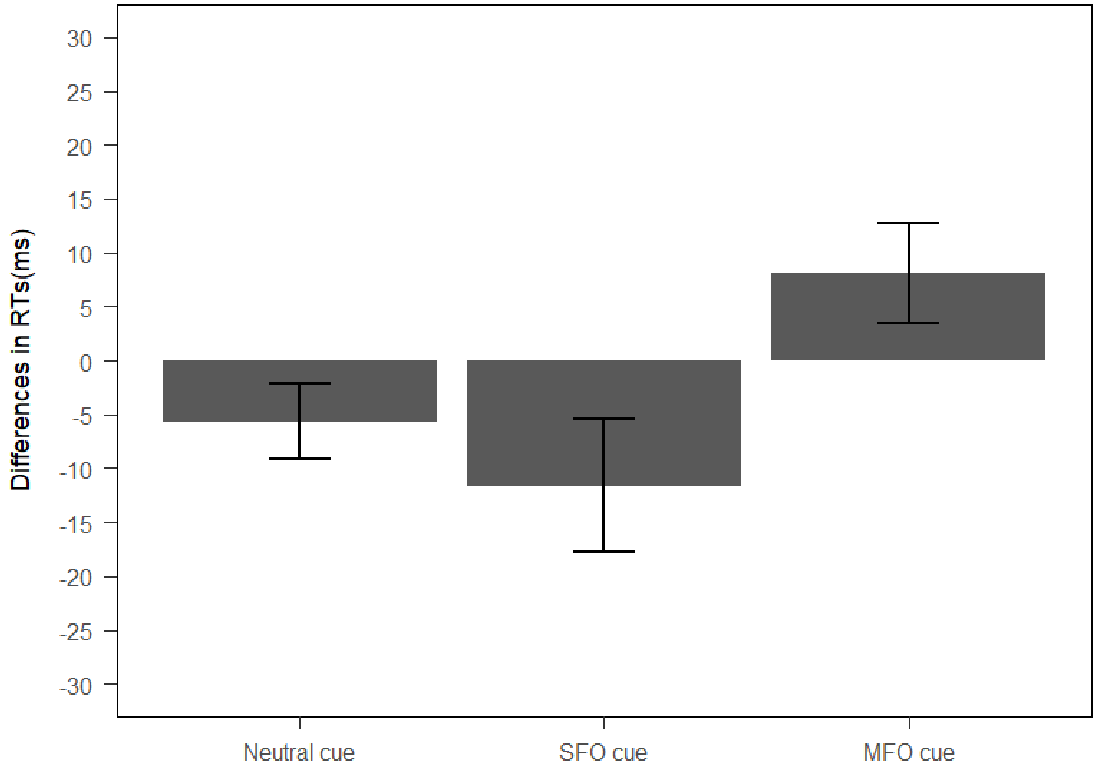

Figure 3. Experiment 1 RT difference in the three cue conditions of the test phase (Error bar represents one standard error). SFO represents the single-functional outcome, and MFO represents the multi-functional outcome. Note: A positive score represents faster multi-functional responses, and a negative score represents faster single-functional responses.

Accuracy

Figure 4 shows the accuracy difference pattern in the three cue conditions. The planned contrast yielded no significant effect (F (1, 50) = 2.65, p = .110). Although not significant, please note that the accuracy pattern shows that participants responded more accurately to the multi-functional outcome response (vs. single-functional outcome response) when encountering the multi-functional outcome cue. This suggests that the RTs effect cannot be easily explained by a speed-accuracy trade-off.

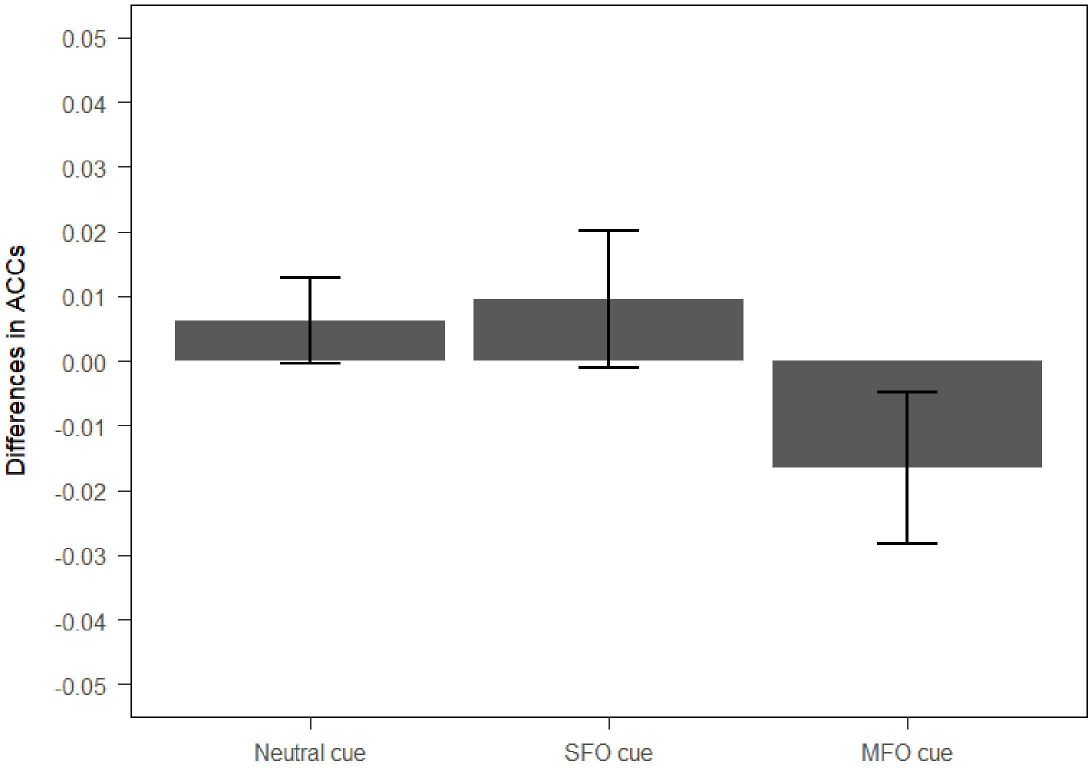

Figure 4. Experiment 1 accuracy difference in the three cue conditions of the test phase (Error bar represents one standard error). SFO represents the single-functional outcome, and MFO represents the multi-functional outcome. Note: A negative score represents more accurate multi-functional responses, and a positive score represents more accurate single-functional responses.

Self-report data

The separate t-tests indicated that participants liked the multi-functional snack more (M = 3.94, SD = 1.08) than the single-functional snack (M = 3.29, SD = 1.03, t (50) = 2.92, p = .005, *Cohen's* d_z = 0.41). Furthermore, they were willing to spend more effort to get the multi-functional snack (M = 3.37, SD = 1.26) compared to the single-functional snack (M = 2.75, SD = 1.16, t (50) = 3.11, p = .003, *Cohen's* d_z = 0.44). They also reported higher motivation to get the multi-functional snack (M = 3.59, SD =1.20) compared to the single-functional snack (M =3.18, SD = 1.14, t (50) = 2.10, p = .041, *Cohen's* d_z = 0.29). In short, the self-reports clearly show that the multi-functional (vs. the single-functional) candy bar was perceived as more valuable.

Discussion

The results of Experiment 1 provide initial evidence that cue-based goal-directed behavior is more likely to materialize for behaviors that are represented as having multi-functional (vs. single-functional) outcomes. Taking the RTs of single-functional and multi-functional snack responses to neutral cues as a baseline, the significant planned contrast of RTs indicates that cues associated with the multi-functional snack facilitated multi-functional snack responses, while cues associated with the single-functional snack did not facilitate single-functional snack responses.

It is important to note that the manipulation regarding the multi-functionality remained rather implicit. The single function of eating the snack immediately after the study explicitly forced participants to use the object in one way. However, we do not know whether participants experienced the freedom of choice and considered other purposes than eating when taking the snack home. In other words, whereas participants represented the 'NOW' snack in terms of being forced to use it in one way, it can be questioned whether they represented the 'HOME' snack as an object they could use in different ways and thus were free in using it. If the two snacks do not differ in multi-functionality representations, our findings could be ascribed to the higher likeability of taking the snack home and not to multi-functional value per se. To examine the multi-functionality aspect more thoroughly, we conducted a second experiment where the multi-functionality of the snack manipulation was designed to be very explicit in terms of being forced or free in using the same snack in one way or several ways, respectively.

Experiment 2

To corroborate the findings of Experiment 1, we more strongly relied on the need for autonomy (Ryan & Deci, 2000, 2006), which explicitly deals with restricted freedom of choice or not and is at the essence of human motivation. Participants could again earn a candy bar snack, but we explicitly enforced the single-functional snack by telling participants that they could only do one thing with it, namely eating it after the experiment. Furthermore, for the multi-functional snack, we made it explicitly clear that the candy bar could be used for several purposes after the experiment by providing three example options: eating it themselves, giving it away to another person, or giving it back to the experimenter to receive money for it in return. We did not make any references about taking the snack home. Accordingly, we made clear that participants were *forced* to use one snack only in one way (single-functional object condition), while they were *free* to use the other snack in multiple ways (multi-functional object condition). Building on the findings of Experiment 1, and research on personal autonomy and freedom of choice, we tested whether participants' responses were facilitated by Pavlovian cues associated with the multi-functional candy bar versus the cues associated with the single-functional candy bar. This experiment was pre-registered in OSF[2].

Method

Participants and design

We increased the sample size to obtain a more sensitive measure for detecting a specific PIT effect, and we recruited 60 participants (14 males, mean age 25.85, *SD* = 6.78). Data from two participants were excluded since one had excessively low accuracy in the test phase (< 3 *SD* from the sample mean), and the other participant responded extremely slowly (> 3 *SD* from the sample mean). The remaining 58 participants were subjected to the 2 (Response outcome: single-functional vs. multi-functional) x 3 (Cue outcome: neutral vs. single-functional vs. multi-functional) repeated measures design experiment. They received a fixed amount of 10 Euros[3] as a participation fee before the experiment. Like Experiment 1, they could earn two candy bars; one they were forced to consume (single-functional), and one were free in whatever they wanted to do with it (multi-functional).

Apparatus and materials

Apparatus and materials were the same as in Experiment 1 except for the image of outcomes that appeared in the learning phases and the questionnaire. In direct correspondence with the concept of personal freedom of choice, we replaced the text below the candy bar image with 'FORCED' and 'FREE' to represent the single and multi-functional outcomes, respectively. Accordingly, we revised the questionnaire to capture the forced and free wording, including 7 items. We measured liking, attractiveness, and desire to take each snack home. As a seventh item, we asked participants to indicate which of the two snacks they preferred. The self-report items

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[2] https://osf.io/e4rcj/?view_only=319a7cd9bd0a4bf7900105d7c6c75d87

[3] This amount was higher than experiment 1 because the Covid-19 measures made the experiment for participants more invasive with all the extra precautions that needed to be taken.

were measured on a 9-point Likert scale since it might produce a larger comparative variance to reveal differences between items, and it might increase reliability compared to the 5-point Likert scale (Finn, 1972; Oaster, 1989) (see the supplemental materials, Appendix C).

Procedure

The procedure was mostly the same as Experiment 1, but this experiment was run during the Covid-19 pandemic, and specific precautions were taken. We followed the Covid-19 protocol of Utrecht University when running the study. Specifically, the experimenter kept a distance of 1.5 m from participants during the entire experiment. Furthermore, the experimenter did not stay with participants in the same cubicle but used video and microphones to communicate with participants and monitor the progress of the experiment. At the end of the experiment, participants filled out the questionnaire. Finally, they received the two snacks. One of the snacks they had to consume, and for the other, they were reminded of the multiple options, including the option to exchange the snack for a monetary reward. In total, 34 participants exchanged the snack for money (i.e., €0,50), and 26 participants chose to do something else with it.

Data preparation and analyses

Like Experiment 1, we trimmed the RT data of the correct responses in the test phase for outliers (3.9 % of RT data), which is defined as slower or faster than 3 *SD* of each participant's mean (Lachaud & Renaud, 2011). Since the RTs and the accuracies were non-normally distributed, we performed a reciprocal transformation for both the RTs and the accuracies. Following up on the findings of Experiment 1, we predicted that specific PIT effects should only be observed in the multi-functional outcome cue condition. We, therefore, calculated the difference for the RT and the accuracy data and analyzed them with the same approach as Experiment 1.

For analyzing the self-report data, we conducted three paired t-tests (2-tailed) to compare the self-report scores of liking, attractiveness, and to what extent participants wanted to take the single-functional and the multi-functional snack home, respectively. We also did a one-sample t-test on the preference item to test which snack participants preferred.

Results

Reaction times

Figure 5 shows the pattern of RT difference in the three cue conditions. The planned contrast yielded a significant contrast effect (F (1, 57) = 6.12, p = .016, η_p^2 = .10 [0.010; 0.232]). The pattern indicated that in the multi-functional outcome cue condition, the RT difference score between the single-functional outcome response and the multi-functional outcome response is larger and positive compared to the RT difference score in the other two conditions. The RT difference did not seem to differ between the neutral and single-functional cue conditions.

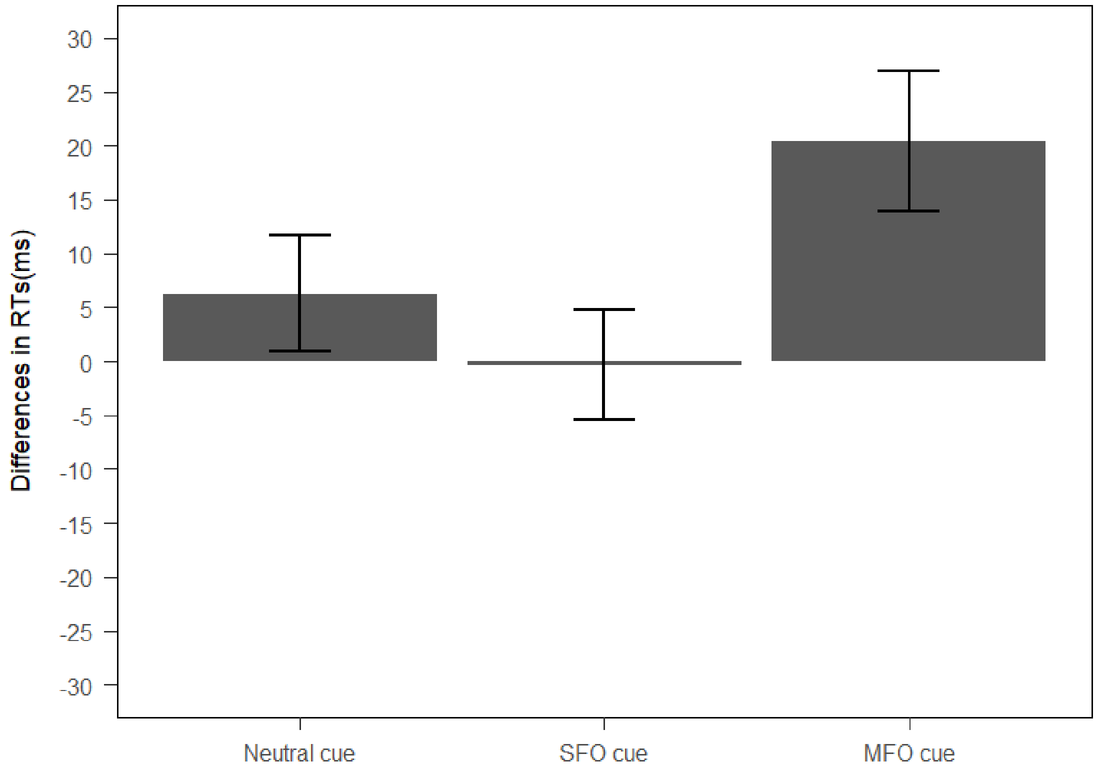

Figure 5. Experiment 2 RT difference in the three conditions of the test phase (Error bar represents one standard error). SFO represents the single-functional outcome, and MFO represents the multi-functional outcome. Note: A positive score represents faster multi-functional responses, and a negative score represents faster single-functional responses.

Accuracy

The planned contrast for accuracy difference in the three cue conditions was not significant (F (1, 57) = 1.49, p = .227). The accuracy difference pattern is presented in Figure 6.

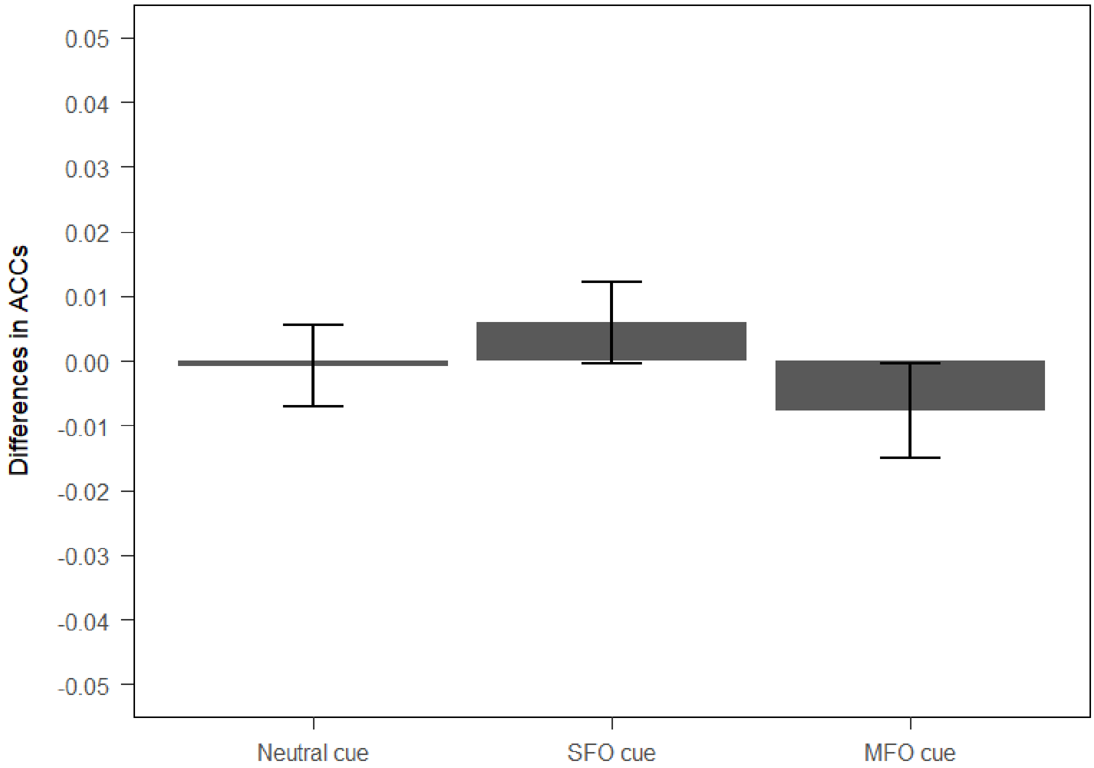

Figure 6. Experiment 2 accuracy difference in the three conditions of the test phase (Error bar represents one standard error). SFO represents the single-functional outcome, and MFO represents the multi-functional outcome. Note: A negative score represents more accurate multi-functional responses, and a positive score represents more accurate single-functional responses.

Self-report data

The results indicated that participants liked the multi-functional snack (M = 6.62, SD = 2.12) more than the single-functional snack (M = 5.12, SD = 2.33, t (57) = 4.54, p < .001, *Cohen's* d_z = 0.60). They also felt the multi-functional snack (M = 6.84, SD = 1.72) was more attractive compared to the single-functional snack (M = 4.62, SD = 2.38, t (57) = 7.15, p < .001, *Cohen's* d_z = 0.94). Importantly, we did not find a difference in how much participants liked to take the multi-functional snack (M = 5.98, *SD* = 2.98) or the single-functional snack home (*M* = 5.76, *SD* = 2.84, *t* (57) = 0.44, *p* = .661), suggesting that we ruled out the possibility that the multi-functional object is merely represented as a snack that one likes to take home. Additionally, the one-sample t-test, which examined whether participants favored the multi-functional snack compared to the single-functional snack by comparing the score with the median value of 5, indicated that participants had a strong preference for the multi-functional snack (*M* = 8.17, *SD* = 1.44, *t* (57) = 16.77, $p < .001$, *Cohen's* d_z = 2.20). Taken together, these results offer clear evidence that participants valued the multi-functional snack more than the single-functional one.

Discussion

The findings of Experiment 2 replicated the value-based specific PIT effect observed in Experiment 1; cues associated with the multi-functional snack increased the expected difference in response times between multi-functional and single-functional snack responses, while the neutral cue and the cue associated with the single-functional snack did not produce these differences in response times. In contrast to Experiment 1, the multi-functionality manipulation was not confounded with where and when to use the snack. In Experiment 2, we made it more explicit that a snack served only one purpose or multiple purposes by listing examples of such purposes. It was, therefore, clear to participants that they were *forced* to use one snack in one way and were *free* to use the other snack in different ways.

General discussion

The present study examined whether cues can gain motivational control over goal-directed behavior by exploiting the PIT paradigm in a forced-choice reaction time test. According to specific PIT, cues can trigger outcome-related actions when such outcome is of personal value, even though a person has not directly learned to perform the action in response to the cue. So far, PIT research has focused on actions with one single functional outcome. Research on the hierarchical organization of human behavior suggests that actions can serve multiple outcomes and goals at different levels of decision-making, offering flexibility and degrees of freedom in engaging in goal-directed behavior (Carver & Scheier, 1981; Kruglanski et al., 2002; Vallacher & Wegner, 1987). Hypothesizing that actions that can serve multiple outcomes are perceived to be more valuable, we tested whether PIT effects are stronger for actions serving multiple outcomes. Overall, our findings indicate that specific PIT effects are more pronounced for actions related to objects that serve multiple purposes than for objects that serve only one purpose, suggesting that a multi-functionality context changes PIT effects by increasing the motivational strength by which Pavlovian cues can trigger goal-directed behavior.

It is important to note that previous research established the motivational nature of specific PIT for goal-directed actions in a setting where two actions each had one single (low or high-value) outcome. Furthermore, these outcomes consisted of objects (e.g., cucumber or chocolate) that differ in perceptual information (e.g., Alarcón et al., 2018; Alarcón & Bonardi, 2016; Qin et al., 2021; Watson et al., 2016). Whereas the observed PIT effects in earlier research may result from the differences in motivational relevance attached to the objects, other features of the stimulus objects (e.g., ease of processing, familiarity) might also contribute to the effects. In the present study, we used one single stimulus object (e.g., a candy bar) and manipulated the psychological meaning of the object. We framed the very same object as having one function or multiple functions. As earlier research indicates, multi-functional objects offer more freedom in acting and achieving different goals and are therefore perceived as more valuable (Bijleveld & Aarts, 2014; Han et al., 2009; Kruglanski et al., 2015; Ryan & Deci, 2006). This notion was corroborated by the checks in the present studies. In line with an outcome value-based account, stressing the multi-functionality of an object rendered the same object more prone to PIT.

Our findings suggest that the PIT forced-choice task can separate cue-based goal-directed behavior with multiple outcomes versus one single outcome. Although encouraging, a few important notes are in place to put these effects in broader perspectives. First, in the present study, the snack was selected based on participants' personal preferences; hence, the snack should be associated with experienced pleasure. Earlier research has found specific PIT effects for pleasurable objects (e.g., Allman et al., 2010). Considering this, a rather notable finding in the present study is that a specific PIT effect did not clearly show up in the single outcome condition representing a pleasurable object. Two possible reasons may account for the observed pattern. Firstly, although not investigated, it is possible that in previous research, participants considered the objects (e.g., food and drinks) as having multiple functions. Research suggests that people differ in how they represent their actions in terms of different goals (van der Weiden et al., 2010; Vallacher & Wegner, 1987). Hence, earlier studies might have established PIT effects partly due to the perceived multi-functionality of the objects obtained by the instrumental actions.

A second possibility pertains to the manipulation and experimental design of the present study. We forced participants to consider one initially pleasurable object with only one functionality, which decreased their experiences of personal autonomy and freedom of choice. Because freedom of choice is essential in determining individuals' internal motivation (Deci & Ryan, 1985; Ryan & Deci, 2000), it is possible that the single-functional outcome completely lost its value because of the pain of losing freedom. Furthermore, using this manipulation in a within-subject design might have created a comparison between the two snacks and, as revealed by the self-reported checks, caused participants to consider the single-functional snack relatively less valuable than the multi-functional snack. Such considerations, then, might have overridden the initial pleasure experiences of the snack. Whereas comparisons between two objects are less likely to occur in a between-subject design, future research could explore whether the experimental design of testing can explain the absence of the specific PIT effect for single functional objects.

Furthermore, we wish to note that our study followed an outcome value comparison approach in which action, cues, and outcomes of different values (single vs. multi-functional) become associated because of two separate learning processes: Instrumental and Pavlovian learning. Whereas our outcome value comparison approach was able to demonstrate a value-based specific PIT effect, it might be informative to combine this approach with the devaluation approach (Dickinson & Balleine, 1994). According to this approach, stimuli that influence responses through the activation of goal representations should have less of an effect on behavior if the goal is rendered less valuable (i.e., devaluated). Specifically, one could create conditions that render outcomes less relevant or useful, which should mainly affect PIT effects for high-value outcomes. For instance, informing participants that both snacks are expired should remove the PIT effect of the earlier represented multi-functional snack. Moreover, the outcome devaluation procedure can also be used in a reversed way, examining whether PIT effects show up when the value of the outcome is increased (Eder & Dignath, 2016b). For example, one could inform participants that the single-functional snack can also be used in several ways, causing a PIT effect in the earlier represented single-functional snack condition. In general, integrating the outcome value comparison and devaluation approach allows for a full test in showing the dynamics of how cues trigger goal-directed behavior when values of goals come and go in the situation at hand (Aarts, 2007; Marien et al., 2013).

Finally, the current findings may have important implications for research on habits. Habits are often regarded as involuntary actions resulting from stimulus-response (S-R) links that operate automatically and rule out freedom of choice (Wood & Rünger, 2016). However, research using the PIT paradigm suggests that these effects can also be mediated by the activation of goal representations. As our research suggests that responses that serve multiple outcomes can have a stronger effect on behavior than responses that serve a single outcome, researchers may be prone to overestimate the habitual nature of multi-functional responses (c.f., De Houwer, et al., 2018). To properly determine the habitual nature of behavior, especially in more applied and societal contexts, it may be important not only to consider whether there are goals that could mediate these effects but also how many potential goals the behavior could serve (see Marien et al., 2019 for a more elaborate discussion).

To conclude, the present study shows that representing the same action-outcome in terms of a single-functional vs. multi-functional object alters how outcome-related actions respond to cues. In everyday life, people might experience the freedom of choice when they represent their actions in terms of serving different goals according to the context in which they are relevant. For example, taking a soda from the fridge upon entering the kitchen can be represented as a means to satisfy thirst after sports but represented as an act of hospitality when friends come over to watch a movie. Previous research has examined the cognitive and motivational aspects of the process underlying the representation and control of goal-directed behavior (Aarts & Elliot, 2012; Ajzen & Kruglanski, 2019). However, less attention has been given to empirically addressing how goal-directed behaviors with multiple functions are causally linked to and triggered by the environment (but see Custers & Aarts, 2010). We hope that the present research may connect the study of multi-functionality, freedom of choice, and PIT to understand better how actions that can serve different goals can become under the control of the environment.

CHAPTER
5

Chapter 5:

From action initiation to persistence: A Pavlovian-to-instrumental transfer analysis for cue-based goal pursuit

This chapter is based on: Qin, K., Marien, H., Custers, R., & Aarts, H. (2023c). From Action initiation to persistence: A Pavlovian-to-instrumental transfer analysis for cue-based goal pursuit. *Motivation Science*. https://doi.org/10.1037/mot0000298

Credit author statement:

KQ: Conceptualization, Methodology, Investigation, Writing-Original-Draft, Writing-Review & Editing, Visualization. **HM**: Conceptualization, Methodology, Writing-Review & Editing, Supervision. **RC**: Conceptualization, Writing-Review & Editing. **HA**: Conceptualization, Methodology, Writing-Review & Editing, Project administration, Supervision.

Abstract

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 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 (vs. 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

Introduction

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 needs to pull harder to access the drink. Thus, the full motivational nature of goal-directed behavior consists of two successive components: action initiation – i.e., the speed of selecting the appropriate action in response to the goal-relevant cues, and action persistence – i.e., 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 less clear whether such environmental control speaks to the full motivational nature of goal-directed behavior (Marien et al., 2019). The present study addresses this question by relying on a test 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 test (hereafter abbreviated as PIT). In the PIT paradigm, participants undergo instrumental and Pavlovian learning, where they acquire relations between responses and rewarding outcomes (R-O links) and between stimulus cues and the outcomes (S-O links). The cue and response thus share the same outcome. Evidence for a specific PIT effect is provided when the Pavlovian cue triggers the response that was learned to be instrumental in obtaining the outcome, particularly when the transfer addresses an outcome that has value to participants (Cartoni et al., 2016; Holland, 2004; Jeffs & Duka, 2017; Mahlberg et al., 2021; Pessiglione et al., 2008). 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 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 the effort that people spend 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 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 the initiation of 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 objects slowed down less steeply compared to tapping in response to objects that were not outcomes. Thus, while the speed of action initiation was goal-directed, the persistence of engaging in it revealed the full motivational nature of the value of outcomes.

We adapted this task for the forced-choice response time PIT used by Qin et al. (2021). Participants learned to press two different keys to gain high-value (20 cents) and low-value (5 cents) rewards. They also learned to associate the rewards with two different cues. Thus, the cue and response share the same rewarding 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. According to value-driven PIT, the cue associated with high (vs. low) reward motivates the high reward response, while such motivational effect is not expected to occur for the low reward response. In line with the Qin et al. study (2021), 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, then 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 the value of the cue.

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 within the planned time window of the study. We 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 males; mean 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.

[1] We implemented a sensitivity analysis to reveal the minimum effect size that could reliably yield a statistically significant result (Perugini et al., 2018). 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.

***Instrumental learning phase*[3].** Participants had to press the correct key 20 times to collect a coin (See Figure 1, panel A). 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 grey square presented for 1 to 3 seconds (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 R-O mapping. Participants first engaged in 20 practice trials and then moved to the 20 actual trials. They were told that 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 second, followed by a blank screen for 1 second. At the end of the phase, they received information about their extra earnings, up to €1.25.

Pavlovian learning phase. Trials (Figure 1, Panel B) started with a grey square shown in the screen center for 1 to 3 seconds (random time interval). Then, a 'star' or a 'moon' appeared for 1 second. 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', this time when they saw a 'star' or a 'moon' (the particular S-O 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 second. At the end of the phase, they received information about their extra earnings, which were €1.25[4].

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

[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.

Test phase (hallway task). Participants performed 40 randomly presented trials in total, and each condition (i.e., high vs. low-value responses * high vs. low-value cues) was repeated ten times (See Figure 1, panel C). Whereas in the instrumental learning task, coins appeared in the middle of the hallway, in the test task, one of the two cues (a 'star' or a 'moon') appeared instead. 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 had to press 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 of the screen. If participants initiated a wrong response, a red cross appeared for 1 second, and only the hallway background appeared for 1 second. After each key press, the cue was increased by 12.5 pixels, and thus the impression was created that the cue was brought closer to the participant by pressing the key. 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 second. Note that participants did not earn any coins in this task[5].

Following Marien et al. (2015), in this task, 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]

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[5] After the test task, four manipulation checks were administered to assess whether participants correctly recalled the R-O and S-O associations (see the supplementary materials, Appendix D). In the end, a questionnaire assessed experiences of the task (this is not further discussed in the paper; descriptions can be found in the supplementary materials, Appendix D).

[6] The method is based on a previous experiment that yielded null results (more details in the supplemental materials, Appendix D). 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.

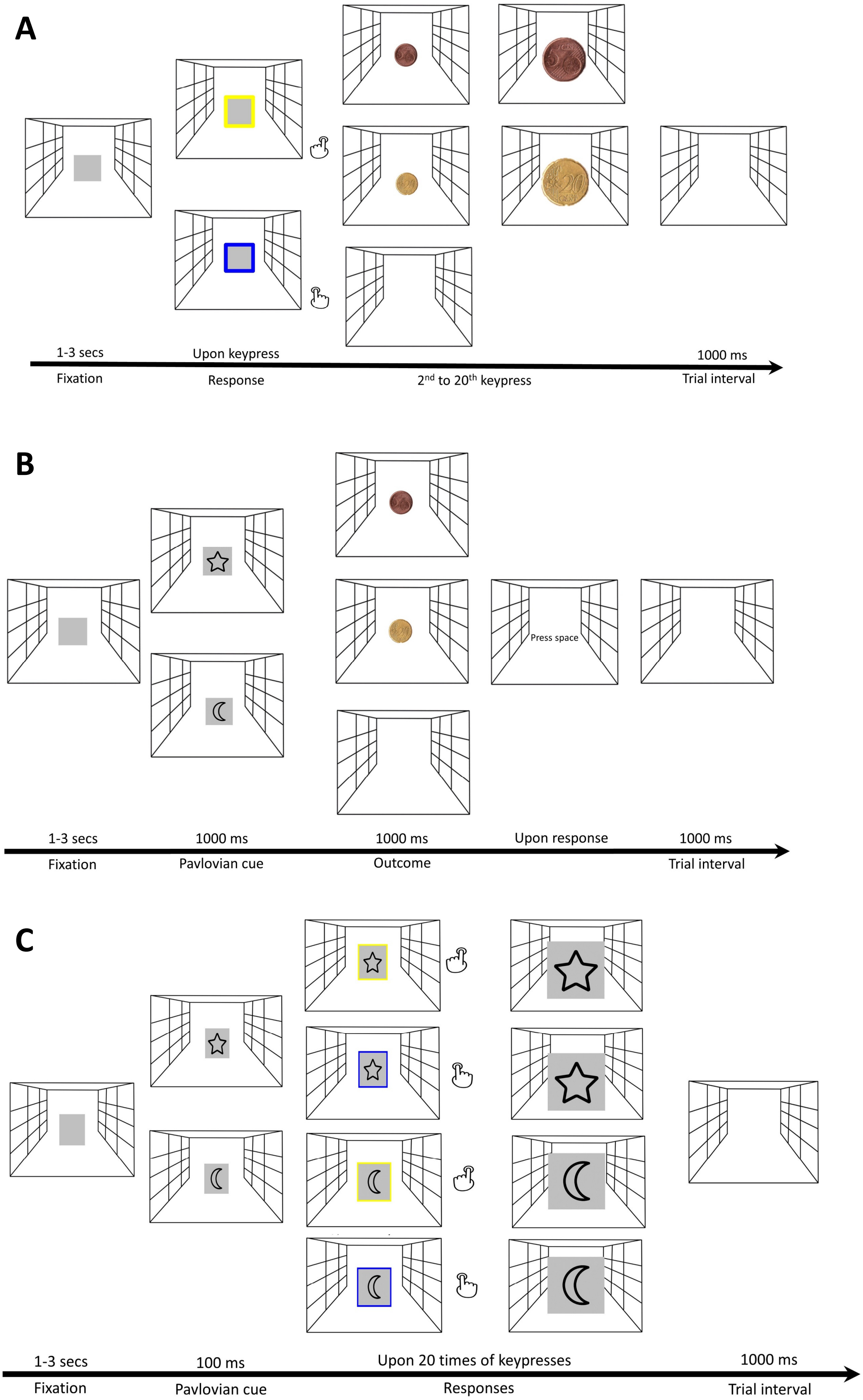

Figure 1. Flowchart of correct responses in Instrumental learning task (A), Pavlovian learning task (B), and Transfer task (C).

Data preparation and analysis

The data preparation and analysis are the same as Qin et al. (2021). We trimmed the first response 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 20^{th} response RTs that were either incorrect or faster than 60 ms (Pinet et al., 2017) or slower than 3 *SD* of the participant's mean (4.9% of the second to the 20^{th} 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 ($\eta^2{}_p$) 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, -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).

Results

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

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[7] We did the transformation because these data were not normally distributed (see the details in the supplementary materials, Appendix D). 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 and analyses of accuracy data can be found in supplementary materials, Appendix D as well.

[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].

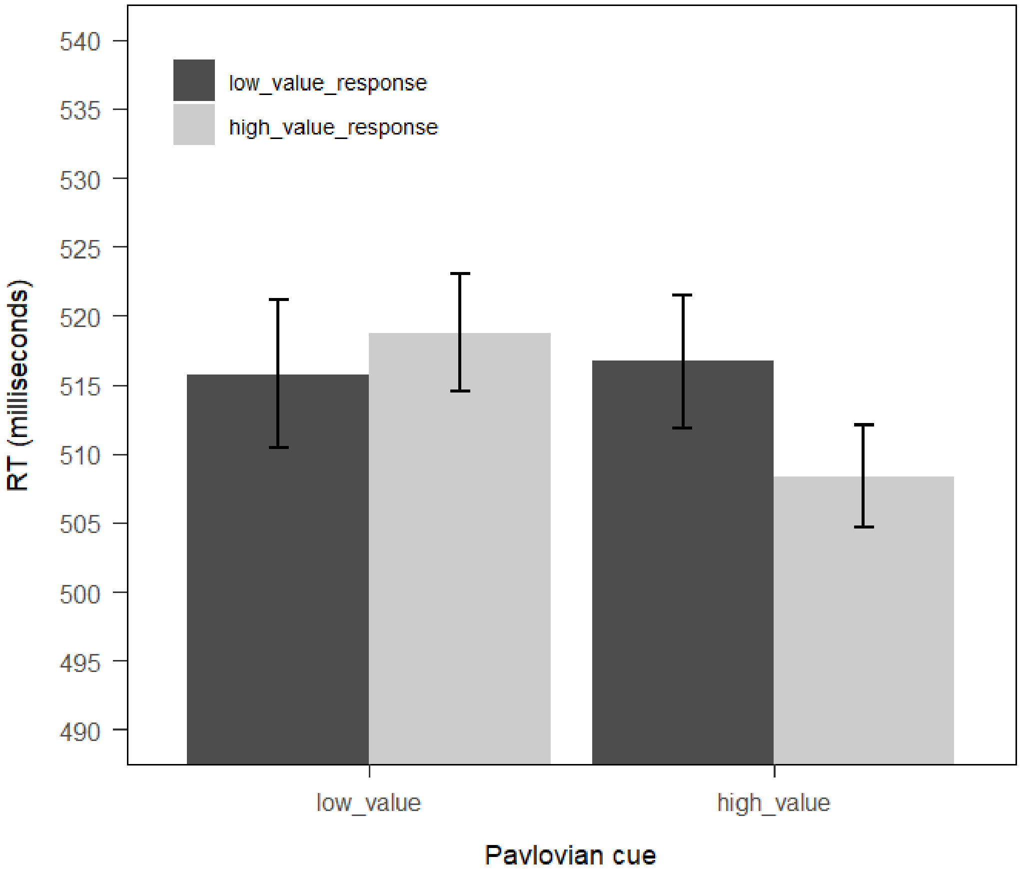

Figure 2. Reaction times pattern of the first response in the test phase. Error bars represent one standard error of the mean.

Reaction times of the remaining responses

The analyses showed that the contrast was not significant (F (1, 102) = 0.43, p = .516, η_p^2 = .00[0.000; 0.049]). The linear effect of remaining responses was significant (F (1, 102) = 145.73, p = < .001, η_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, η_p^2 = .00[0.000; 0.051]). Figure 3 presents the RTs pattern of the remaining keypresses.

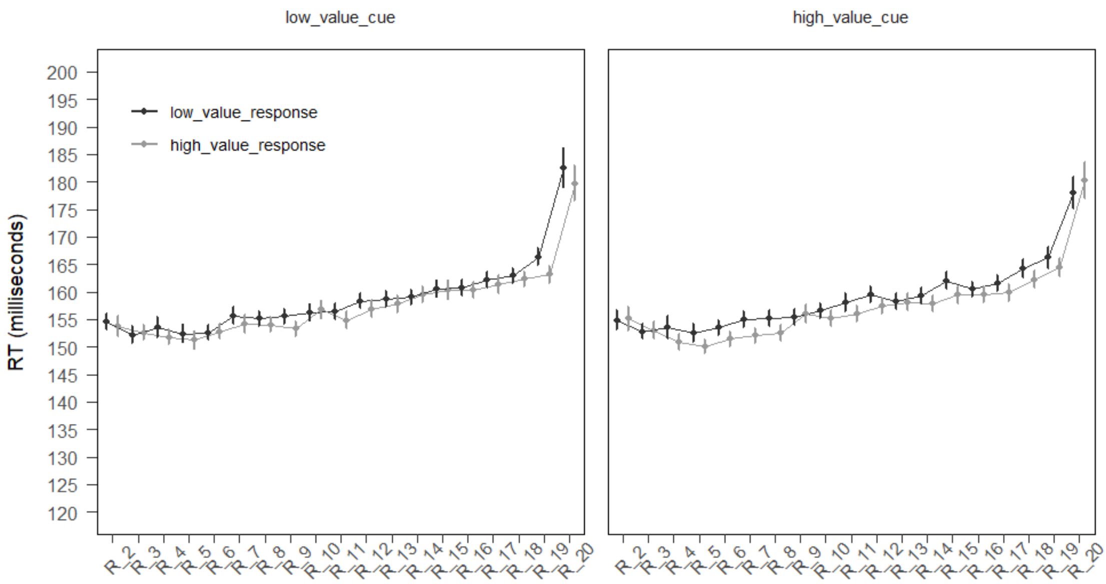

Figure 3. Reaction times pattern of the remaining key presses in the test phase. Error bars represent one standard error of the mean. Note: x-axis represents the number of presses in the test phase.

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 speed of 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 (vs. low) value outcome, replicating earlier findings (Qin et al., 2021). However, no effect occurred for the remaining responses. Within the context of 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 a reaction-time task. Despite this, we note that the obtained effect on RTs is still likely caused by Pavlovian-to-instrumental transfer 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 participants were unwilling to spend effort to obtain the cues. Research on the behavioral, neurophysiological, and computational implementation of effort suggests that effort investment is subject to resources conservation: Individuals avoid wasting energy and invest resources only for outcomes that are attainable and valuable (Bijleveld et al., 2012a; 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 be motivating in itself (Brown & Jenkins, 1968; Williams & Williams, 1969). Future research could address more precisely how cues can facilitate effort in human goal-directed behavior.

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Appendices

Appendix A: Supplementary materials for Chapter 2

Exp1 Instrumental training RT

Descriptive analysis for the RT

Table 1 Descriptive of the RTs in the instrumental phase of Exp 1

	Mean	SD
high_value_response	469.75	142.06
low_value_response	506.80	170.74

Normality test

We tested the RT distribution for each level of the response value. The result shows that both of them violate the normal distribution assumption (see Table 2).

Table 2 Results of Shapiro-Wilk Normality Test for RTs of Exp 1 Instrumental training

	w_value	p_value
high_value_response	0.852	<0.001
low_value_response	0.855	<0.001

RT test

After the reciprocal transformation, the paired t test indicates that participants responded faster on higher value trials (t (39) = 2.77, p = .009, $Cohen'd_z$ = 0.44 [0.11; 0.76]).

Exp1 instrumental training accuracy

Normality test and data transformation

The same Shapiro-Wilk Normality Test and reciprocal transformation were applied to the accuracy of instrumental training. Details can be found in table 3.

Table 3 Results of Shapiro-Wilk Normality Test for accuracy of Exp 1 Instrumental training

	w_value	p_value
high_value_response	0.351	<0.001
low_value_response	0.342	<0.001

Accuracy test

We used an F-test instead of a t-test in this test because previous studies demonstrated that F-test is robust even when the sample is not normally distributed (Lantz, 2013; Blanca et al.,2017). The F-test was fed by transformed accuracy.

The result indicated that no difference between high and low-value responses was detected (Transformed accuracy: F (1, 39) = 0.16, p = .693).

Exp1 Contingency learning

We tested the accuracy of responses in instrumental training and the accuracy of the oral report in instrumental training task and Pavlovian training task to infer whether participants have learned the R-O and S-O contingency.

Table 4 Descriptive analysis of response error and oral report error in Instrumental and Pavlovian phase

	Mean	SD
Response error in instrumental training	0.011	0.029
Oral report error in instrumental training	0.007	0.026
Oral report error in Pavlovian training	0	0

The result of the actual task of instrumental training and Pavlovian training indicates that participants have learned the R-O and the S-O contingency.

Exp1 test phase RT

Normality test

We tested the RT distribution for each cell of the combination of two independent variables (response value & Pavlovian cue value). The result shows that all of them violate the normal distribution assumption (see Table 5).

Table 5 Results of Shapiro-Wilk Normality Test in the test phase of Exp 1

	w_value	p_value
high_value_cue_high_value_response	0.818	<0.001
high_value_cue_low_value_response	0.802	<0.001
low_value_cue_high_value_response	0.900	0.002
low_value_cue_low_value_response	0.788	<0.001

Exp1 test phase accuracy

Normality test

Details can be found in Table 6.

Table 6 Results of Shapiro-Wilk Normality Test for accuracy in the test phase of Exp 1

	w_value	p_value
high_value_cue_high_value_response	0.601	<0.001
high_value_cue_low_value_response	0.591	<0.001
low_value_cue_high_value_response	0.576	<0.001
low_value_cue_low_value_response	0.502	<0.001

Exp 1 Descriptive analysis

Table 7 Exp 1 Descriptive analysis

Instrumental response	Pavlovian_cue	RT_Means	RT_SDs	ACC_Means	ACC_SDs
high_value_response	high_value_cue	416.128	90.548	0.967	0.059
high_value_response	low_value_cue	425.293	72.456	0.970	0.056
low_value_response	high_value_cue	442.376	96.336	0.964	0.067
low_value_response	low_value_cue	427.962	90.000	0.972	0.065

Exp2 Instrumental training RT

RT's descriptive analysis

Table 8 Descriptive analysis of RTs in the instrumental phase of Exp 2

	Mean	SD
high_value_response	537.34	191.78
low_value_response	552.47	201.27

Normality test

Repeat the same analysis procedure as we did in experiment 1 and see the result in Table 9.

Table 9 Results of Shapiro-Wilk Normality Test for the RTs of Exp 2 Instrumental training

	w_value	p_value
high_value_response	0.887	<0.001
low_value_response	0.931	0.003

RT test

After reciprocal transformation, the paired t-test was implemented and it still indicates no difference between high and low responses (t (55) = 1.48, p = .145).

Exp 2 instrumental training accuracy

Normality test

Details can be found in table 10.

Table 10 Results of Shapiro-Wilk Normality Test for accuracy of Exp 2 Instrumental training

	w_value	p_value
high_value_response	0.326	<0.001
low_value_response	0.322	<0.001

Accuracy test

The result indicated that no difference between high and low-value responses was detected (Transformed accuracy: F (1, 55) = 0.11, p = .742).

Exp 2 contingency learning

We tested the accuracy of responses in instrumental training and accuracy of the oral report in instrumental training task and Pavlovian training task to infer whether participants have learned the R-O and S-O contingency.

Table 11 Results of response error and oral report error in instrumental and Pavlovian phase

	Mean	SD
Aggregated response error in the instrumental training	0.010	0.026
Average oral report error in the instrumental training	0.006	0.017
Average oral report error in Pavlovian training	0	0

The result indicates that participants have learned the R-O and the S-O contingency.

Exp2 test phase RT

Normality test

Similar test as we did in experiment 1 test phase (Results see Table 12).

Table 12 Results of Shapiro-Wilk Normality Test for the RTs Exp 2 Instrumental training

	w_value	p_value
high_value_cue_high_value_response	0.963	0.086
high_value_cue_low_value_response	0.882	<0.001
low_value_cue_high_value_response	0.954	0.034
low_value_cue_low_value_response	0.933	0.004

Exp2 test phase accuracy

Normality test

Details can be found in table 13.

Table 13 Results of Shapiro-Wilk Normality Test for accuracy in the test phase of Exp 2

	w_value	p_value
high_value_cue_high_value_response	0.761	<0.001
high_value_cue_low_value_response	0.807	<0.001
low_value_cue_high_value_response	0.760	<0.001
low_value_cue_low_value_response	0.666	<0.001

Exp 2 Descriptive analysis

Table 14 Exp 2 Descriptive analysis

Instrumental response	Pavlovian_cue	RT_Means	RT_SDs	ACC_Means	ACC_SDs
high_value_response	high_value_cue	457.913	71.635	0.981	0.024
high_value_response	low_value_cue	467.340	79.487	0.970	0.040
low_value_response	high_value_cue	471.022	95.093	0.969	0.037
low_value_response	low_value_cue	460.695	84.352	0.974	0.041

Appendix B: Supplementary materials for Chapter 3

Information about the charities

Against Malaria (shown in Experiment 1 and Experiment 2)

The Against Malaria Foundation is raising funds and awareness to help people fight against the deadly disease of Malaria. About half a million people each year die from Malaria, and 220 million falls ill. 70% of them are children under 5. It is the number 1 killer of pregnant women. Every 100-1,000 nets put over heads and beds, one child does not die. Every single net matters.

Details about this charity can be found at: https://www.againstmalaria.com/

Give Directly (shown in Experiment 2)

GiveDirectly provides unconditional cash transfers using cell phone technology to some of the poorest people in Kenya, Uganda, and Rwanda. These direct cash transfers allow families to buy much-needed food and shelter, educate their children, and start small businesses. GiveDirectly uses national data and door-to-door surveys to seek out the poorest households to receive transfers. Recipients are selected using a range of criteria that vary by region, including housing materials, assets, and vulnerable recipient status. Selected households are provided with SIM cards if they do not have one.

Details can be found at: https://www.givedirectly.org/

Global Alliance for Improved Nutrition(GAIN): Salt Iodization Program (shown in Experiment 2)

Iodine is a vital micronutrient for mental and physical health, yet in many parts of the world, people do not have enough iodine in their normal diet. There is a simple, cost-effective solution: fortifying household salt with iodine. Fortifying salt with iodine is safe, relatively easy, has high returns on investment, and is extremely inexpensive. Depending on the country and its level of support needed, GAIN can begin, expand or sustain a salt iodization program to cover an individual over an entire year at an estimated 15 to 45 Euro cents. Benefits include improved health, improved educability, lower health care costs. The cost per person is around 0,15 to 0,45 euros, and it is higher in countries with low iodization coverage and populations that are difficult to reach than in countries that are improving or just sustaining their salt iodization programs.

Details can be found at: https://www.gainhealth.org/resources/reports-and-publications/universal-salt-iodization-provides-sufficient-dietary-iodine

The total amount of donated money

We counted how much money that participants donated in each experiment. In Experiment 1, participants donated € 61, which accounted for 63.5% of money initially reserved for donations. And in Experiment 2, participants donated € 145.5 in total, which accounted for 121.3% of money reserved for donations

Descriptives about the donation to the charities (Experiment 2)

Table 1 Descriptives of money donations in Experiment 2

Charities	Amount sum	Frequencies	Percentage	Percentage Frequencies
1	7,550(cents)	30	51.89%	50.00%
2	2,950(cents)	17	20.27%	28.33%
3	4,050(cents)	13	27.84%	21.67%

Note: **Charity 1** refers to the Against Malaria Foundation; **Charity 2** refers to the Give Directly Foundation; and **Charity 3** refers to the Global Alliance for Improved Nutrition (GAIN): Salt iodization Program.

Amount_sum: Total amount of donated money.

Frequencies: how many times this charity has been donated.

Precentage_amount: The proportion of the amount of money donated to the charity.

Precentage_Frequencies: The proportion of frequencies of donated charities.

Exp 1 instrumental training RTs

Descriptive analysis

Table 2 Descriptive analysis of Exp 1 instrumental training (actual task)

Response	RT_mean	RT_sd	ACC_mean	ACC_sd
self-interest response	464.237	115.005	0.974	0.044
other-interest response	465.056	94.954	0.996	0.020

Normality test

Table 3 Normality test of the instrumental training RTs (actual task)

Items	w_value	p_value
self-interest response	0.834	<0.001
other-interest response	0.831	<0.001

Table 4 Normality test of instrumental training accuracy (actual task)

Items	w_value	p_value
self-interest response	0.543	<0.001
other-interest response	0.206	<0.001

RT and Acc test

The results indicate that no difference was found on RTs[1] (t (46) = 0.76, p = .449), but the test on accuracy (t (46) = 3.15, p = .003, Cohen'd_z = 0.46) indicates that participants responded more accurately on the other-interest response than the self-interest response in the instrumental training phase.

Exp 1 test phase RTs and ACC

Descriptive analysis

Table 5 descriptive analysis of Exp 1 test phase

Response	Cue	RT_mean	RT_sd	ACC_mean	ACC_sd
self-interest response	neutral cue	427.800	73.183	0.974	0.046
self-interest response	self-interest cue	420.825	67.463	0.984	0.039
self-interest response	other-interest cue	430.092	70.269	0.967	0.049
other-interest response	neutral cue	431.499	72.681	0.976	0.035
other-interest response	self-interest cue	433.823	64.245	0.971	0.071
other-interest response	other-interest cue	426.997	65.027	0.969	0.043

[1] The DVs used in all analyses have been reciprocally transformed.

Normality test

Table 6 Normality test of the test phase RTs

Items	w_value	p_value
self-interest response & neutral cue	0.819	<0.001
self-interest response & self-interest cue	0.844	<0.001
self-interest response & other-interest cue	0.804	<0.001
other-interest response & neutral cue	0.847	<0.001
other-interest response & self-interest cue	0.880	<0.001
other-interest response & other-interest cue	0.860	<0.001

Table 7 Normality test of test phase accuracy

Items	w_value	p_value
self-interest response & neutral cue	0.633	<0.001
self-interest response & self-interest cue	0.486	<0.001
self-interest response & other-interest cue	0.701	<0.001
other-interest response & neutral cue	0.681	<0.001
other-interest response & self-interest cue	0.430	<0.001
other-interest response & other-interest cue	0.723	<0.001

Exp 2 instrumental training RTs

Descriptive analysis

Table 8 Descriptive analysis of Exp 2 instrumental training phase (actual task)

Response	RT_mean	RT_sd	ACC_mean	ACC_sd
self-interest response	467.715	120.200	0.986	0.035
other-interest response	474.309	129.754	0.981	0.044

Normality test

Table 9 Normality test of the instrumental training RTs (actual task)

Items	w_value	p_value
self-interest response	0.767	<0.001
other-interest response	0.826	<0.001

Table 10 Normality test of instrumental training accuracy (actual task)

Items	w_value	p_value
self-interest response	0.409	<0.001
other-interest response	0.476	<0.001

RT and Acc test

The results indicate that no difference was found on RTs (t (57) = 0.21, p = .835) and accuracy (t (57) = -0.76, p = .449) in the instrumental training phase.

Exp 2 test phase RTs and ACC

Descriptive analysis

Table 11 Descriptive analysis in the test phase

Response	Pav_cue	RT_mean	RT_sd	ACC_mean	ACC_sd
self-interest response	neutral cue	419.964	70.150	0.979	0.032
self-interest response	self-interest cue	419.825	66.675	0.974	0.058
self-interest response	other-interest cue	420.714	64.052	0.967	0.052
other-interest response	neutral cue	428.396	84.469	0.978	0.039
other-interest response	self-interest cue	429.441	80.417	0.973	0.036
other-interest response	other-interest cue	414.531	65.086	0.972	0.049

Normality test

RTs

Table 12 Normality test of the test phase RTs

Items	w_value	p_value
self-interest response & neutral cue	0.900	<0.001
self-interest response & self-interest cue	0.899	<0.001
self-interest response & other-interest cue	0.949	0.016
other-interest response & neutral cue	0.867	<0.001
other-interest response & self-interest cue	0.909	<0.001
other-interest response & other-interest cue	0.946	0.012

ACC

Table 13 Normality test of test phase accuracy

Items	w_value	p_value
self-interest response & neutral cue	0.665	<0.001
self-interest response & self-interest cue	0.513	<0.001
self-interest response & other-interest cue	0.681	<0.001
other-interest response & neutral cue	0.609	<0.001
other-interest response & self-interest cue	0.733	<0.001
other-interest response & other-interest cue	0.612	<0.001

Appendix C: Supplementary materials for Chapter 4

The questionnaire used in Exp 1

Please answer the following questions about the snack of choice.

Tick the box that fits best with your opinion.

1. To what extent would you like to eat the snack right now?

Not at all – not much – neutral – somewhat – very much

2. How much effort would you make to be able to eat the snack right now?

Not at all – not much – neutral – somewhat – very much

3. To what extent are you motivated to eat the snack right now?

Not at all – not much – neutral – somewhat – very much

4. To what extent would you like to take the snack home with you?

Not at all – not much – neutral – somewhat – very much

5. How much effort would you make to be able to take the snack home with you?

Not at all – not much – neutral – somewhat – very much

6. To what extent are you motivated to take the snack home with you?

Not at all – not much – neutral – somewhat – very much

Exp 1 instrumental training RTs

Descriptive analysis

Table 1 Descriptive analysis of Exp 1instrumental training

Response	RT_mean	RT_sd	ACC_mean	ACC_sd
SFO response	464.633	92.634	0.984	0.042
MFO response	469.203	85.563	0.996	0.020

Note: SFO: Single-functional outcome; MFO: Multi-functional outcome

Normality test

Table 2 Normality test of the instrumental training RTs

items	w_value	p_value
SFO response	0.941	0.013
MFO response	0.933	0.007

Table 3 Normality test of instrumental training accuracy

items	w_value	p_value
SFO response	0.421	<0.001
MFO response	0.196	<0.001

RTs and ACC test

The results indicate that no difference was found on RTs[1] (t (50) = 1.16, p = .254) and accuracy (t (50) = 1.76, p = .084) in instrumental training phase.

Exp 1 test phase RTs and ACC

Descriptive analysis

Table 4 descriptive analysis of Exp 1 test phase

Response	Cue	RT_mean	RT_sd	ACC_mean	ACC_sd
SFO response	Neutral cue	403.191	50.999	0.979	0.046
MFO response	SFO cue	393.651	49.297	0.976	0.036
SFO response	MFO cue	405.237	49.558	0.958	0.065
MFO response	Neutral cue	408.819	53.253	0.973	0.037
SFO response	SFO cue	405.282	56.138	0.966	0.054
MFO response	MFO cue	397.128	50.955	0.974	0.047

[1] The DVs used in all analyses have been reciprocally transformed.

Normality test

Table 5 Normality test of the test phase RTs

items	w_value	p_value
SFO response & Neutral cue	0.884	<0.001
SFO response & SFO cue	0.941	0.013
SFO response & MFO cue	0.936	0.008
MFO response & Neutral cue	0.921	0.002
MFO response & SFO cue	0.937	0.009
MFO response & MFO cue	0.940	0.011

Table 6 Normality test of test phase accuracy

items	w_value	p_value
SFO response & Neutral cue	0.531	<0.001
SFO response & SFO cue	0.690	<0.001
SFO response & MFO cue	0.677	<0.001
MFO response & Neutral cue	0.707	<0.001
MFO response & SFO cue	0.678	<0.001
MFO response & MFO cue	0.601	<0.001

The questionnaire used in Exp 2

1.How much do you like the ‘FORCED’ snack that you have to eat immediately?

1(Not at all)-2-3-4-5-6-7-8-9(Very much)

2.How attractive is the ‘FORCED’ snack to you?

1(Not at all)-2-3-4-5-6-7-8-9(Very much)

3.How much do you like the ‘FREE’ snack you can do with whatever you want?

1(Not at all)-2-3-4-5-6-7-8-9(Very much)

4.How attractive is the ‘FREE’ snack to you?

1(Not at all)-2-3-4-5-6-7-8-9(Very much)

5.Which one would you prefer? Please select a number that fits your answer?

1(‘Forced’ snack)-2-3-4-5-6-7-8-9(‘Free’ snack)

6.Would you like to take the ‘FORCED’ snack home?

1(Not at all)-2-3-4-5-6-7-8-9(Very much)

7.Would you like to take the ‘FREE’ snack home?

1(Not at all)-2-3-4-5-6-7-8-9(Very much)

Exp 2 instrumental training RTs

Descriptive analysis

Table 7 Descriptive analysis of Exp 2 instrumental training phase

response	RT_mean	RT_sd	ACC_mean	ACC_sd
SFO response	499.559	124.833	0.984	0.042
MFO response	492.462	110.812	0.988	0.033

Normality test

Table 8 Normality test of the instrumental training RTs

items	w_value	p_value
SFO response	0.853	<0.001
MFO response	0.899	<0.001

Table 9 Normality test of instrumental training accuracy

items	w_value	p_value
SFO response	0.426	<0.001
MFO response	0.381	<0.001

RTs and ACC test

The results indicate that no difference was found on RTs (t (57) = -0.65, p = .521) and accuracy (t (57) = 0.63, p = .531) in instrumental training phase.

Exp 2 test phase RTs and ACC

Descriptive analysis

Table 10 Descriptive analysis in the test phase

Response	Cue	RT_mean	RT_sd	ACC_mean	ACC_sd
SFO response	Neutral cue	448.796	87.933	0.981	0.033
SFO response	SFO cue	444.299	83.312	0.981	0.035
SFO response	MFO cue	461.468	97.560	0.972	0.046
MFO response	Neutral cue	442.501	64.619	0.981	0.030
MFO response	SFO cue	444.631	66.506	0.975	0.039
MFO response	MFO cue	441.015	61.427	0.980	0.030

Normality test

Table 11 Normality test of the test phase RTs

items	w_value	p_value
SFO response & Neutral cue	0.833	<0.001
SFO response & SFO cue	0.847	<0.001
SFO response & MFO cue	0.807	<0.001
MFO response & Neutral cue	0.934	0.003
MFO response & SFO cue	0.929	0.002
MFO response & MFO cue	0.964	0.085

Table 12 Normality test of test phase accuracy

items	w_value	p_value
SFO response & Neutral cue	0.630	<0.001
SFO response & SFO cue	0.613	<0.001
SFO response & MFO cue	0.663	<0.001
MFO response & Neutral cue	0.636	<0.001
MFO response & SFO cue	0.653	<0.001
MFO response & MFO cue	0.666	<0.001

What participants did with the multi-functional snack in Experiment 2

Twenty-six participants took the multi-functional snack away for other purposes, and thirty-four participants transferred the multi-functional snack for extra 50 euro cents.

Appendix D: Supplementary materials for Chapter 5

A: INFORMATION OF PREVIOUS (PRELIMINARY) EXPERIMENT THAT FAILED TO FIND EFFECTS

Preliminary Experiment

This experiment served as the first test to examine whether the value-sensitive PIT effect of action initiation observed in the previous study (Qin et al., 2021) could be extended to the persistence of action. Qin et al. (2021) found that the speed of responding to a Pavlovian cue was facilitated when the cue and the required response were predictive of the same outcome, and this action preparation effect was more pronounced for the high-value (20 cents) vs. low-value (5 cents) cue condition (Qin et al., 2021). In this experiment, we employed the hallway task and examined whether the outcome value-based effect can also be established on the remaining repeated responses to move the cues to the front as a result of being represented as desirable outcomes. This measure of behavioral approach is taken as an index of persistence of action (e.g., Marien et al., 2015).

In the previous study (Qin et al., 2021), the transfer test task required participants to be as fast as possible to facilitate action preparation as part of a Pavlovian cue priming effect. However, motivation of action, which is often measured by effort investment (e.g., Marien et al., 2015), should not depend on speed instructions (Aarts et al., 2008; Bijleveld et al., 2009). In fact, speed instructions may overrule the motivational effects on effort investment because participants are forced to speed up performance without considering the value of the outcome (Freedman & Edwards, 1988; Friedman et al., 2010). We did not know how the speed instructions would impact the transfer test of the motivational control of goal-directed behavior in the present hallway task. We, therefore, decided to manipulate the speed instructions by explicitly asking one group of participants to respond as quickly as possible while the other group did not receive speed instructions.

Method

Participants and design

We determined the sample size by a simulation-based power analysis (Lakens & Caldwell, 2021) to get a planned contrast effect obtained from the previous study (Qin et al., 2021) for the instruction and no-instruction groups, respectively, with 80% power. The result indicated that at least 55 participants for each group were needed.

Considering the possible dropout in online studies, we decided to recruit at least 50% more participants. Eventually, we were able to recruit 165 participants from Prolific (Palan & Schitter, 2018). All participants were between 18 and 35 and from Eurozone countries. We excluded 4 participants' data from further analysis: one participant performed instrumental training twice; two participants' reaction time was excessively slow (>3SD from sample mean), and one participant's accuracy was excessively low (65%) in the test phase; The remaining 161 participants' data (82 participants without the instruction; 84 males and 2 other genders; mean age 27.50 (*SD*=9.27)) were kept for further analysis. Participants participated in the experiment with a 2 (cue outcomes: low vs. high-value) x 2 (response outcomes: low vs. high-value) x 2 (Speed instruction: no vs. yes) mixed design, with the speed instruction as a between-subject variable.

After finishing the experiment, they received a fixed amount of ￡1.67 and could earn extra money (up to ￡2.28 depending on their performance during the task[1]).

Apparatus and material

We programmed the experimental script in Jspsych (de Leeuw, 2015), which demonstrated good reliability in measuring sequences of keystrokes (Pinet et al., 2017). We deployed the experiment in Gorilla (Anwyl-Irvine et al., 2020). During the learning phases (i.e., Instrumental and Pavlovian learning phases), the screen projected the instructions in black and contained a white background. We used full-color images of a 5-euro cents (250 * 250 pixels visual angle 6.60˚) and a 20-euro cents coin (250 * 250 pixels, visual angle 6.60˚) as outcomes during the training phases and two figures (i.e., a 'star' and a 'moon' visual angle 6.60˚) as Pavlovian cues. Same as the previous study (Qin et al., 2021), the cue appeared inside the grey square (RGB 192 192 192, visual angle 6.60˚) shown in the center of the screen. A yellow or blue frame (visual angle 6.86˚) surrounded the grey squared to prompt responses. We replaced the white background with a hallway background in the hallway task (i.e., the demonstration and the test phases, for details, see the procedure section).

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

Procedure

Once participants clicked the link to participate in the experiment, they were presented with a brief introduction to the experiment. They were informed that this experiment aims to explore how people react to visual stimuli. They were also told that they could earn extra money during the experiment. All participants provided informed consent and demographic information (i.e., gender, handedness, and age). Next, they started the actual experiment. The experiment contained 4 phases: a demonstration phase, an Instrumental learning phase, a Pavlovian learning phase, and a test phase.

Speed instruction manipulation. Participants were randomly assigned to the speed instruction group or no speed instruction group. Following Qin et al. (2021), in the speed instruction group, participants were asked to respond as quickly and accurately as possible to the tasks that required them to give responses to stimuli. These instructions thus pertain to the demonstration, Instrumental learning phase, and test task. In the no-speed instruction group, participants engaged in the experiment without any reference to the speed of responding. They were only told to respond with the correct keys.

Demonstration phase. The experiment started with the hallway task (for details, see the test phase) to familiarize participants with the experimental setup.

Instrumental learning phase. The Instrumental learning phase contained 40 trials (2 blocks). The first 20 trials were practice trials (block 1), in which participants could not earn any coins but could learn and experience the correct response-outcome mapping. The last 20 trials were the actual task (block 2), in which participants could earn the 5 or 20 cents coin in 50% of the trials (i.e., five trials for 5 cents and five trials for 20 cents). Thus 10 trials included coins they actually could earn. The trials in the practice and the actual task were randomly presented, and each condition (i.e., the response may lead to 5 cents, and the response may lead to 20 cents) was repeated ten times for each block. To encourage participants to process the outcome information carefully, they were asked to speak out '5 cents' or '20 cents' upon their response, depending on the particular R-O mapping. If they pressed an incorrect key, a red cross was displayed for 1 second, followed by a blank screen for 1 second. At the end of the phase, they received information about their extra earnings, up to €1.25.

Pavlovian learning phase. Trials (Figure 1, Panel B) started with a grey square shown on the screen center for 1 to 3 seconds (random time interval). Then, a 'star' or a 'moon' appeared for 1 second. 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', this time when they saw a 'star' or a 'moon' (the particular S-O 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 second. At the end of the phase, they received information about their extra earnings, which were €1.25[2].

Test phase (hallway task). Participants performed 40 randomly presented trials in total, and each condition (i.e., high vs. low-value responses * high vs. low-value cues) was repeated ten times (See Figure 1, panel C). Whereas in the instrumental learning task, coins appeared in the middle of the hallway, in the test task, one of the two cues (a 'star' or a 'moon') appeared instead. 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 had to press 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 of the screen. If participants initiated a wrong response, a red cross appeared for 1 second, and only the hallway background appeared for 1 second. After each key press, the stimulus cue was increased by 12.5 pixels, and thus the impression was created that the stimulus cue was brought closer to the participant by pressing the key. 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 second. Note that participants did not earn any coins in this task.

Following Marien et al. (2015), in this task, 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.

[2] 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.

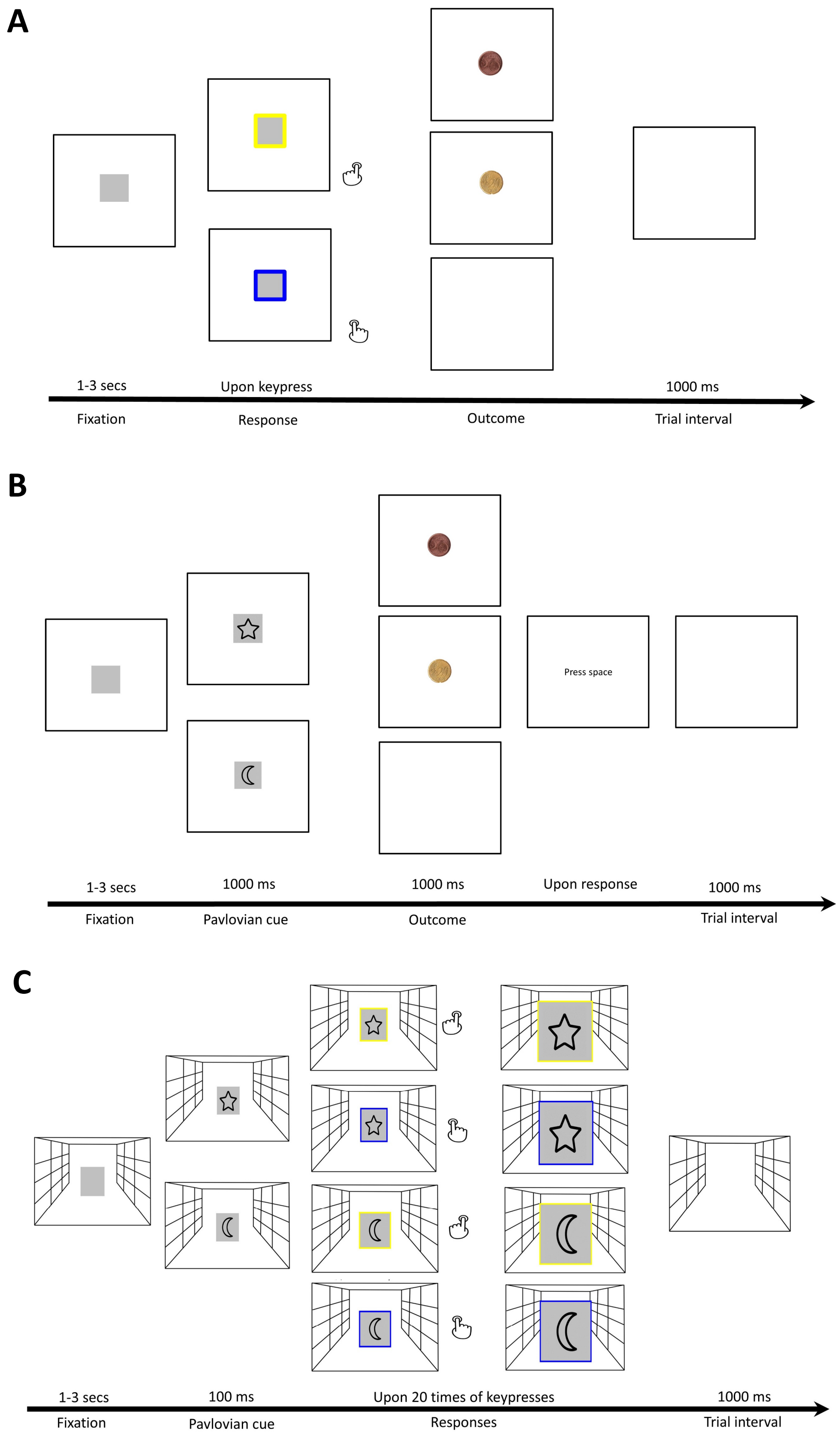

Figure 1. Flowchart of responses in Instrumental learning task (A), Pavlovian learning task (B), and Transfer test task (C) of the experiment

Data preparation and analyses

Firstly, we trimmed the first response RTs data of correct responses in the test phase for outliers (Lachaud & Renaud, 2011) as in previous research (Qin et al., 2021). We removed the first response RTs that were incorrect or slower or faster than 3 SD of the participant's mean (4.4% of the first response RT data). For the second to the 20th response in each test phase trial, we removed the incorrect RTs or faster than 60ms (Pinet et al., 2017) or slower than 3 SD of the participant's mean (5.0% of the remaining RT data). Next, we implemented a reciprocal transformation to the first response RT data, the remaining RT data, and the accuracy data[3] since they were not normally distributed (see the supplementary materials, Appendix D).

We performed a planned contrast for the whole data using an F-test and reported partial eta squared (η^2_p) 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, -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).

Results

Reaction times of the first response

The planned contrast for the reaction time of the first response was not significant (F (1, 159) = 0.01, p = .926, η_p^2 = .00[0.000; 0.000]). The main effect of instructions also was not significant (F (1, 159) = 1.82, p = .180, η_p^2 = .01[0.000; 0.053]). Furthermore, the contrast by instructions interaction effect was not significant either (F

[3] 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. We did not find a significant effect on accuracy; these measures will not be further discussed in this paper. The results can be found in the supplementary materials, Appendix D.

(1, 159) = 0.59, p = .444, η_p^2 = .00[0.000; 0.035]). The RTs pattern of the outcome value cue by outcome value response conditions is presented in Figure 2.

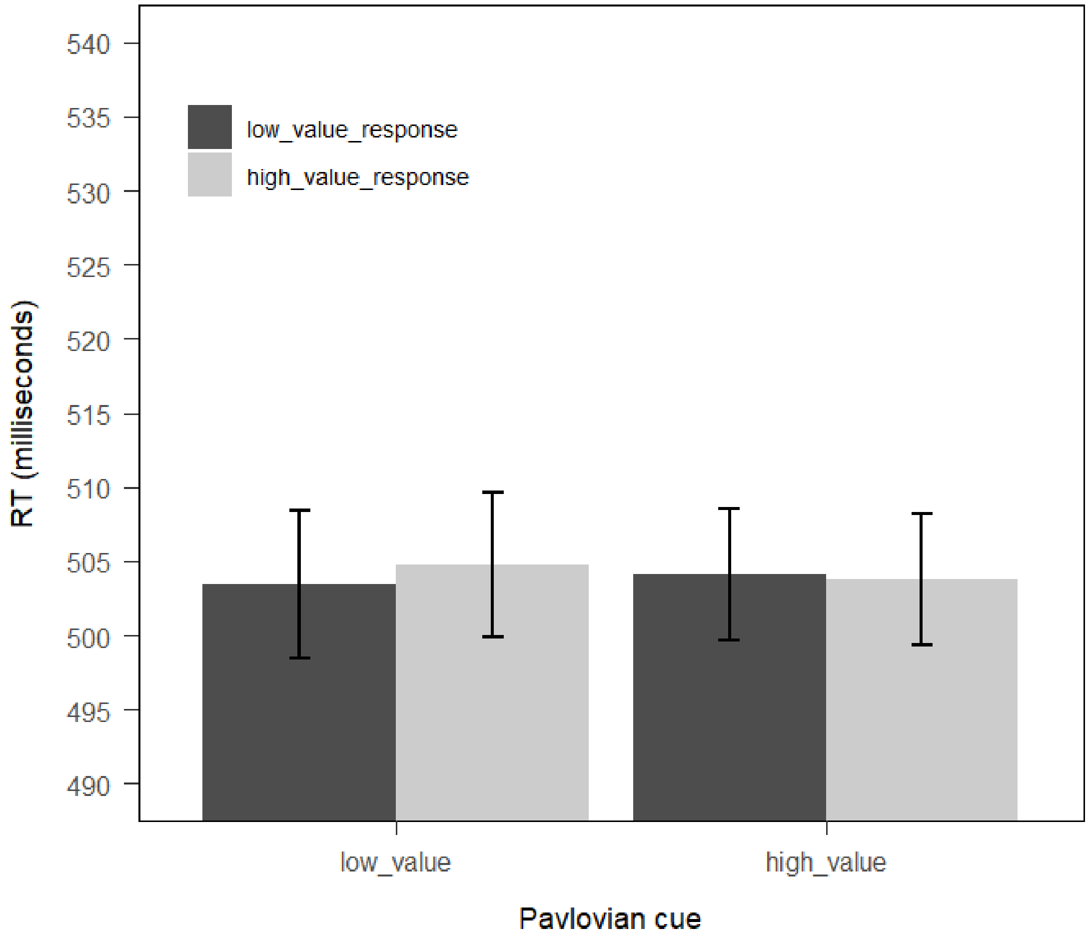

Figure 2. Reaction times pattern of the first response in the test phase (collapsed by instruction groups). Error bars represent one standard error of the mean.

Reaction times of the remaining responses

First, the analyses indicated that the contrast was not significant (F (1, 159) = 1.65, p = .201, η_p^2 = .01[0.000; 0.0531]). Furthermore, there was no significant interaction effect of contrast by the linear effect (F (1, 159) = 1.63, p = .204, η_p^2 = .01[0.000; 0.051]). These results suggest that the PIT effect was absent in the effort measure. Other findings of the ANOVA are: no significant main effect of instructions (F (1, 159) = 3.84, p = .052, η_p^2 = .02[0.000; 0.076]); a highly significant linear effect of remaining responses (F (1, 159) = 152.77, p < .001, η_p^2 = .49[0.402; 0.564]), indicating participants gradually slowed down their speed when finishing the trial. Finally, there were no further interaction effects, revealed by the two-way interaction between contrast by instructions (F (1, 159) = 0.74, p = .390, η_p^2 = .00[0.000; 0.038]), instructions by the linear effect (F (1, 159) = 1.34, p = .249, η_p^2 = .01[0.000; 0.047]), and the three-way interaction between contrast by instructions by the linear effect (F (1, 159) = 0.01, p = .939, η_p^2 = .00[0.000; 0.000]). The pattern of the reaction times of the remaining 19 key presses of the outcome value cue by outcome value response conditions is presented in Figure 4.

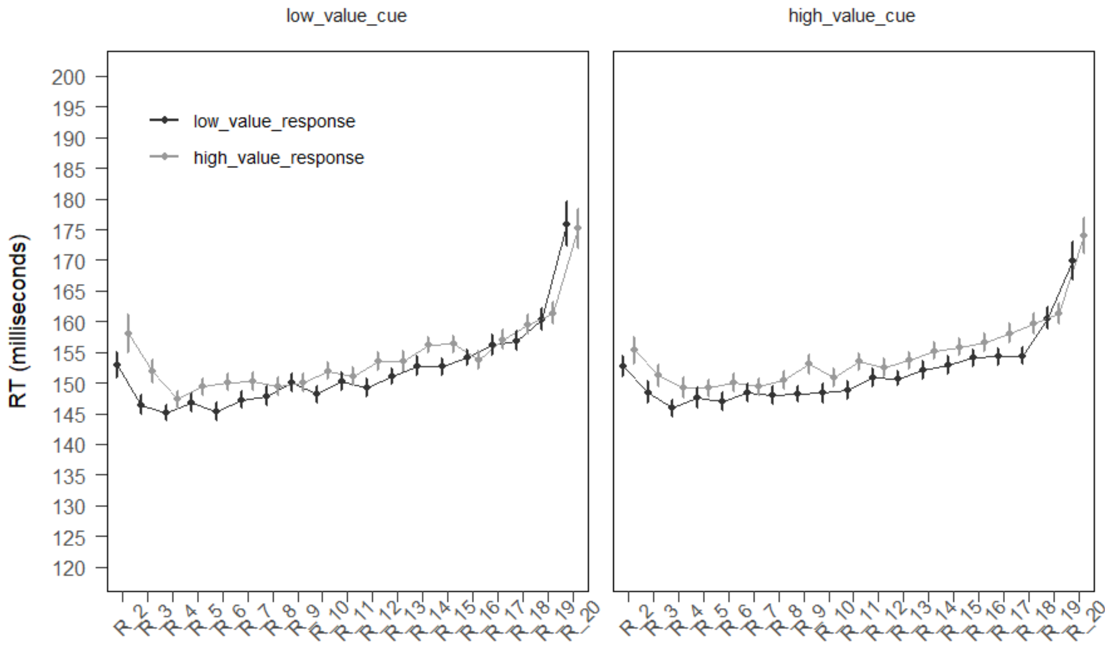

Figure 3. Reaction times pattern of the remaining key presses in the test phase (collapsed across instruction groups). Error bars represent one standard error of the mean. Note: x-axis represents the number of presses in the test phase.

Discussion of results of the preliminary experiment

The preliminary experiment examined whether the specific PIT effect can be observed for the full motivational control of goal-directed behavior using the hallway task that assesses action initiation and persistence of action in the service of outcome attainment. The results are fairly clear and can be summarized as follow: There was no notable effect on the performance (speed and accuracy) of the first response as well as on the performance of the remaining 19 responses. Of interest, the observation that the first response was not sensitive to outcome value-based PIT effects indicates that the effect from the earlier work was not replicated (Qin et al., 2021). The only result that clearly showed up concerned the linear effect of the speed of remaining key presses in the hallway task, indicating that participants became slower over time (see also Marien et al., 2015). In short, then, the findings of the preliminary experiment showed that cues did not affect goal-directed behavior as to action initiation and action persistence.

Whereas this suggests that specific PIT does not hold for the motivational control of cue-based goal-directed behavior, we wish to note two inconsistencies between the learning and the test phases in the preliminary experiment. First, actions and outcomes in Instrumental learning and Pavlovian learning did not fully match the repetitive nature of instrumental actions in the hallway task. Participants in the Instrumental learning task conducted a single response to obtain a single presented coin, and they learned to associate the single presented coin with a single presented Pavlovian cue. This lack of mapping in action and perception might have caused participants to insufficiently apply the knowledge of Instrumental and Pavlovian learning to the test situation (Schütz-Bosbach & Prinz, 2007; Sun et al., 2020; Yu et al., 2014). Second, participants only saw the hallway in the test phase, making the learning and testing context inconsistent. This inconsistency between the learning and testing context may moderate or even extinguish specific PIT effects (Cartoni et al., 2016; Gilroy et al., 2014). Therefore, we revised our experimental setup in a follow-up experiment (reported in Chapter 5) to further explore whether participants are more sensitive to both action initiation and persistence when moving cues to themselves that are associated with the high-value (vs. low-value) outcome.

It is also important to note that our preliminary experiment did not show any meaningful effects of the speed instructions. It could be possible that the speed instructions did not affect action preparation and motivation, or the current paradigm cannot detect such instruction effects. More importantly, the speed instructions might overrule the potential effect on the motivation of action because participants were simply instructed to be faster on responses instead of outcome representations from valuable outcomes. Based on this reasoning, we decided to use no references to the speed of responding to our follow-up experiment.

EXTRA ANALYSES AND RESULTS OF THE PRELIMINARY EXPERIMENT

Instrumental training

Descriptive analysis

Table 1: Descriptive analysis of instrumental training

Response	ins_group	RT_mean	RT_sd	ACC_mean	ACC_sd
low_value	ins_off	573.663	157.556	0.979	0.052
low_value	ins_on	513.424	125.554	0.982	0.039
high_value	ins_off	571.471	165.426	0.988	0.038
high_value	ins_on	503.862	132.194	0.981	0.046

Note: ins_group refers to the instruction group; "ins_off" denotes the no instruction group and "ins_on" denotes the instruction group.

Normality test

RT

Table 2: Normality test of instrumental training RTs

items	w_value	p_value
low_value_ins_off	0.880	<0.001
low_value_ins_on	0.886	<0.001
high_value_ins_off	0.893	<0.001
high_value_ins_on	0.871	<0.001

ACC

Table 3: Normality test of instrumental training ACC

items	w_value	p_value
low_value_ins_off	0.451	<0.001
low_value_ins_on	0.473	<0.001
high_value_ins_off	0.364	<0.001
high_value_ins_on	0.465	<0.001

RT and Acc test

RT

Table 4: ANOVA of the preliminary experiment instrumental training RTs

	num Df	den Df	F	pes	Pr(>F)
ins_group	1	159	9.429	0.056	0.003
response	1	159	6.674	0.040	0.011
ins_group:response	1	159	1.205	0.008	0.274

Note: DVs shown in the RT and Acc Tests have been reciprocally transformed. The main effect of instruction (ins_group) and response value (response) was found. Participants responded faster in the 20 cents condition than in the 5 cents condition, and participants in the instruction group responded faster than in the no instruction group.

ACC

Table 5: ANOVA of the preliminary experiment instrumental training ACC

	num Df	den Df	F	pes	Pr(>F)
ins_group	1	159	0.056	<0.001	0.813
response	1	159	0.712	0.004	0.400
ins_group:response	1	159	1.400	0.009	0.239

Test phase RTs and ACC

Descriptive analysis (the first response)

Table 6: Descriptive analysis of test phase first response RTs and ACC

response	pav_cue	ins_group	RT_mean	RT_sd	ACC_mean	ACC_sd
low_value	high_value	ins_off	510.790	122.353	0.953	0.092
low_value	high_value	ins_on	497.227	104.893	0.956	0.106
low_value	low_value	ins_off	507.958	98.171	0.963	0.084
low_value	low_value	ins_on	498.715	99.132	0.975	0.067
high_value	high_value	ins_off	517.817	122.970	0.978	0.070
high_value	high_value	ins_on	489.148	92.259	0.972	0.078
high_value	low_value	ins_off	511.725	94.501	0.973	0.070
high_value	low_value	ins_on	497.513	113.206	0.968	0.091

Note: Pav_cue denotes Pavlovian cues

Descriptive analysis (remaining responses)

Table 7: Descriptive analysis of test phase rest of responses RTs

response	pav_cue	ins_group	RT_mean	RT_sd
low_value	high_value	ins_off	154.487	28.514
low_value	high_value	ins_on	148.906	28.261
low_value	low_value	ins_off	154.856	28.801
low_value	low_value	ins_on	149.158	28.454
high_value	high_value	ins_off	158.254	30.146
high_value	high_value	ins_on	150.959	30.730
high_value	low_value	ins_off	157.638	31.921
high_value	low_value	ins_on	151.262	30.935

Normality test (the first response)

Table 8: Normality test of test phase first responses RTs

items	w_value	p_value
low_value_r&low_value_cue&ins_on	0.966	0.035
low_value_r&low_value_cue&ins_off	0.950	0.003
low_value_r&high_value_cue&ins_on	0.930	<0.001
low_value_r&high_value_cue&ins_off	0.816	<0.001
high_value_r&high_value_cue&ins_on	0.946	0.002
high_value_r&high_value_cue&ins_off	0.834	<0.001
high_value_r&low_value_cue&ins_on	0.899	<0.001
high_value_r&low_value_cue&ins_off	0.933	<0.001

Note: high_value_r and low_value_r denote response that is predictive of the high (low) value outcome.

Normality test (remaining responses)

Table 9: Normality test of test phase rest of responses RTs

items	w_value	p_value
low_value_r&low_value_cue&ins_on	0.975	0.126
low_value_r&low_value_cue&ins_off	0.983	0.355
low_value_r&high_value_cue&ins_on	0.971	0.068
low_value_r&high_value_cue&ins_off	0.989	0.759
high_value_r&high_value_cue&ins_on	0.940	0.001
high_value_r&high_value_cue&ins_off	0.982	0.326
high_value_r&low_value_cue&ins_on	0.940	0.001
high_value_r&low_value_cue&ins_off	0.985	0.480

Normality test (ACC)

Table 10: Normality test of test phase ACC

items	w_value	p_value
low_value_r&low_value_cue&ins_on	0.390	<0.001
low_value_r&low_value_cue&ins_off	0.471	<0.001
low_value_r&high_value_cue&ins_on	0.467	<0.001
low_value_r&high_value_cue&ins_off	0.538	<0.001
high_value_r&high_value_cue&ins_on	0.406	<0.001
high_value_r&high_value_cue&ins_off	0.344	<0.001
high_value_r&low_value_cue&ins_on	0.392	<0.001
high_value_r&low_value_cue&ins_off	0.412	<0.001

Accuracy of the first response

The planned contrast indicated that the predicted pattern was not significant (F (1, 159) = 2.32, p = .130). The main effect of instructions was not significant (F (1, 159) = 0.64, p = .801). The contrast by instructions interaction effect was not significant either (F (1, 159) = 0.81, p = .776). The accuracy pattern of the outcome value cue by outcome value response conditions is presented in Figure 3.

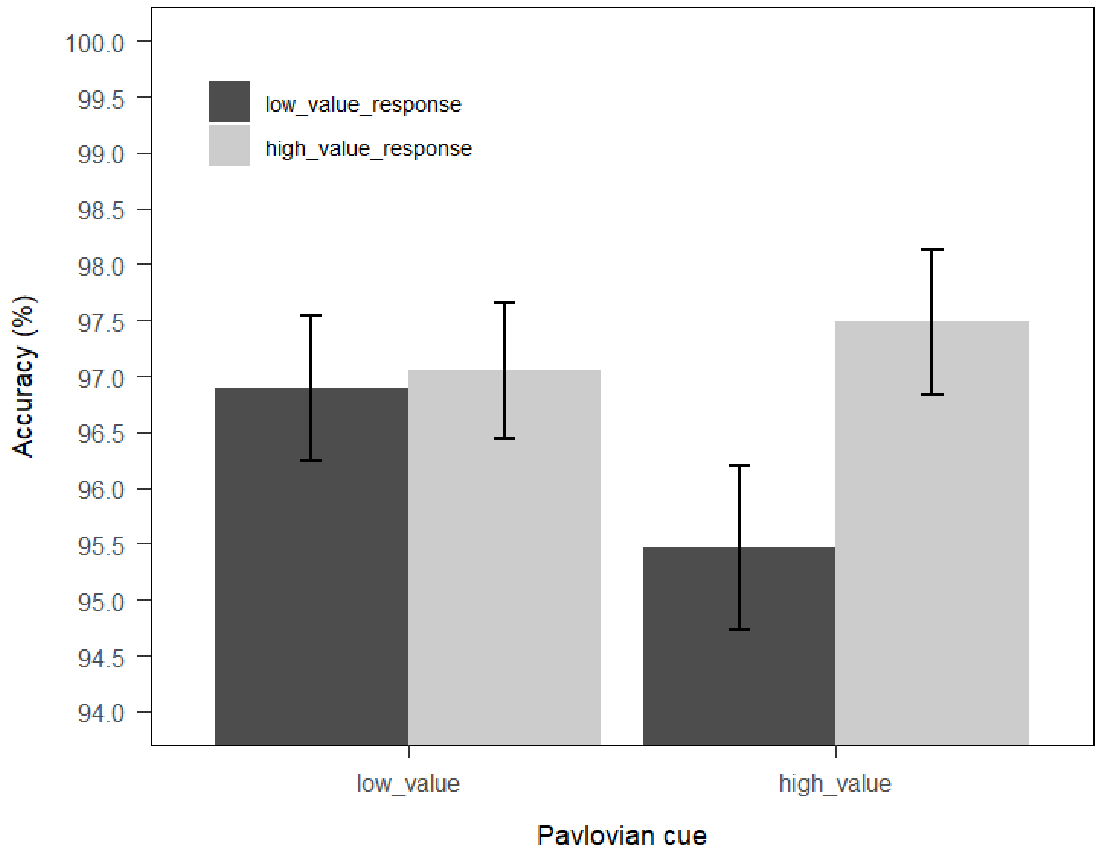

Figure 1. Accuracy pattern of the first response in the test phase (collapsed across instruction groups). Error bars represent one standard error of the mean.

Supplementary plots for the test phase

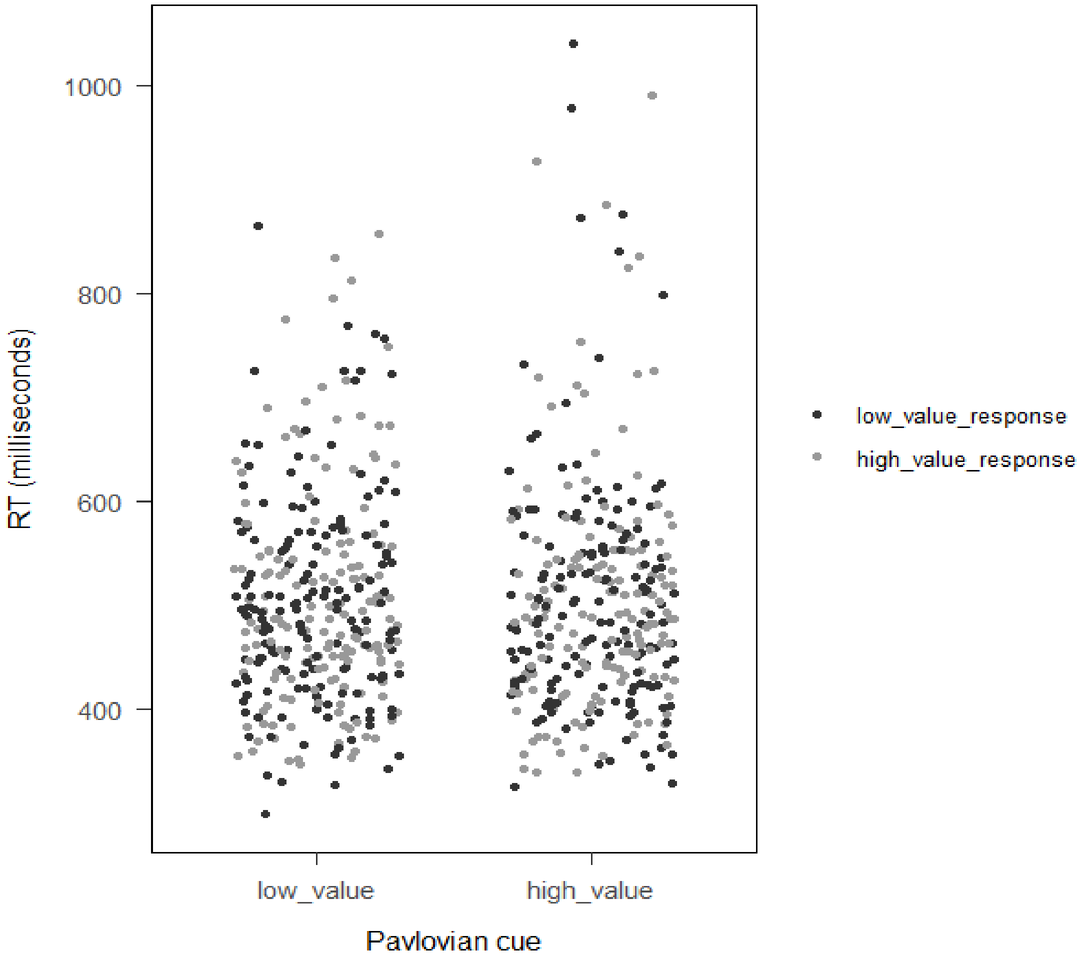

Figure 2, Individual data points first RT

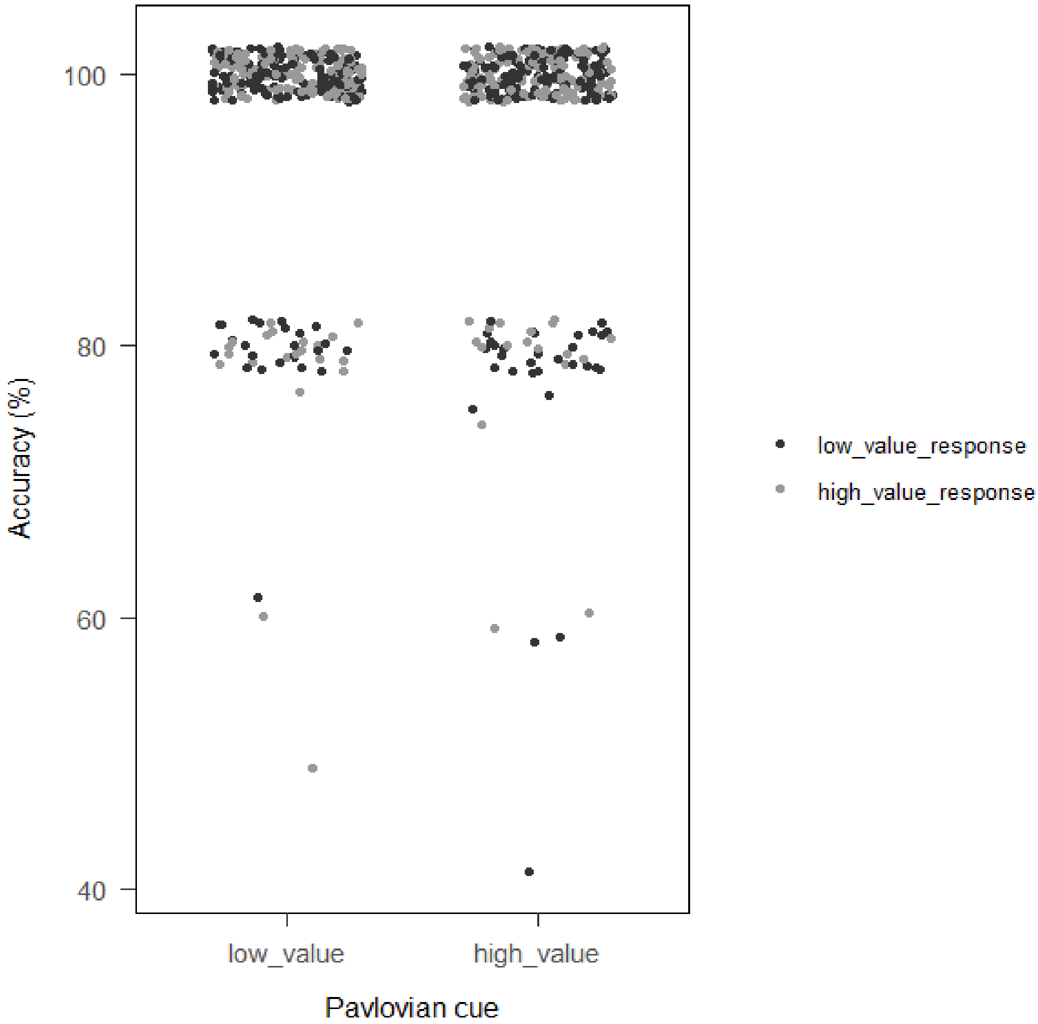

Figure 3, Individual data points ACC

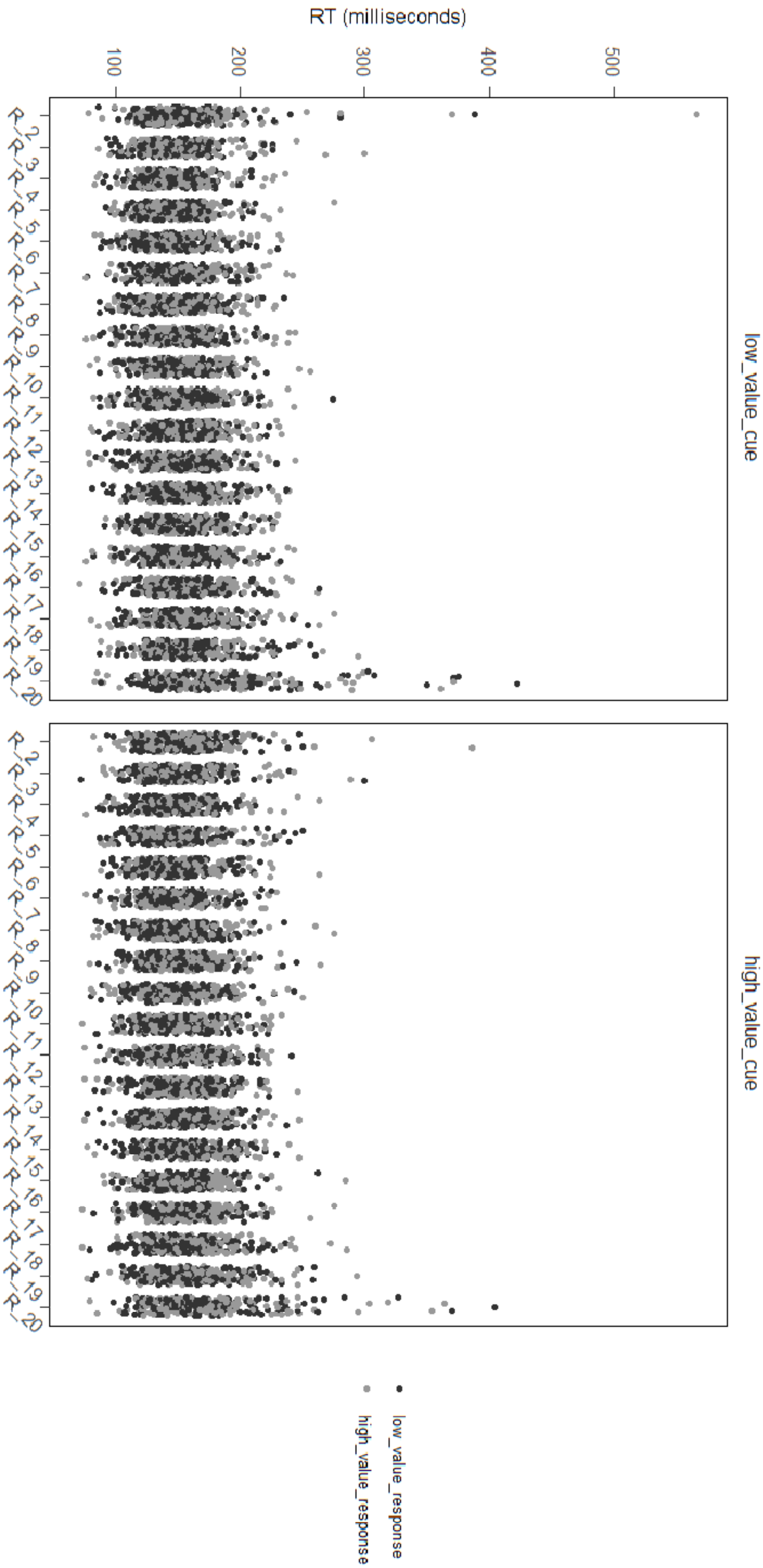

Figure 4, Individual data points remaining RTs

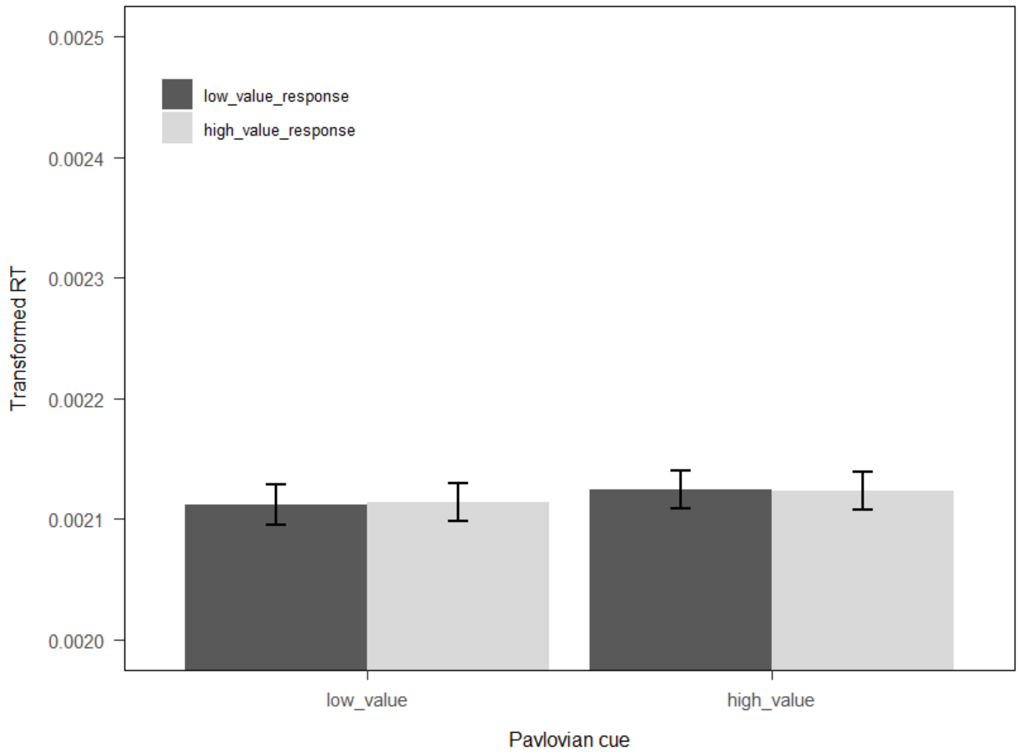

Figure 5, transformed first response RT

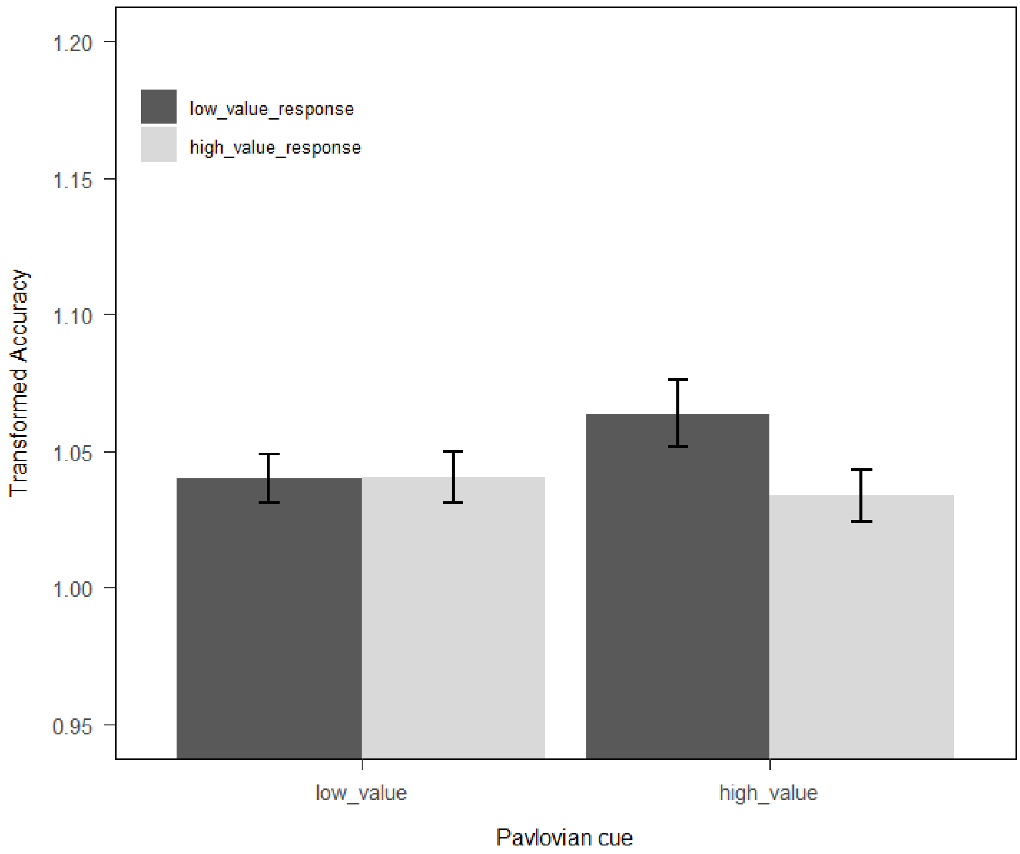

Figure 6, transformed ACC

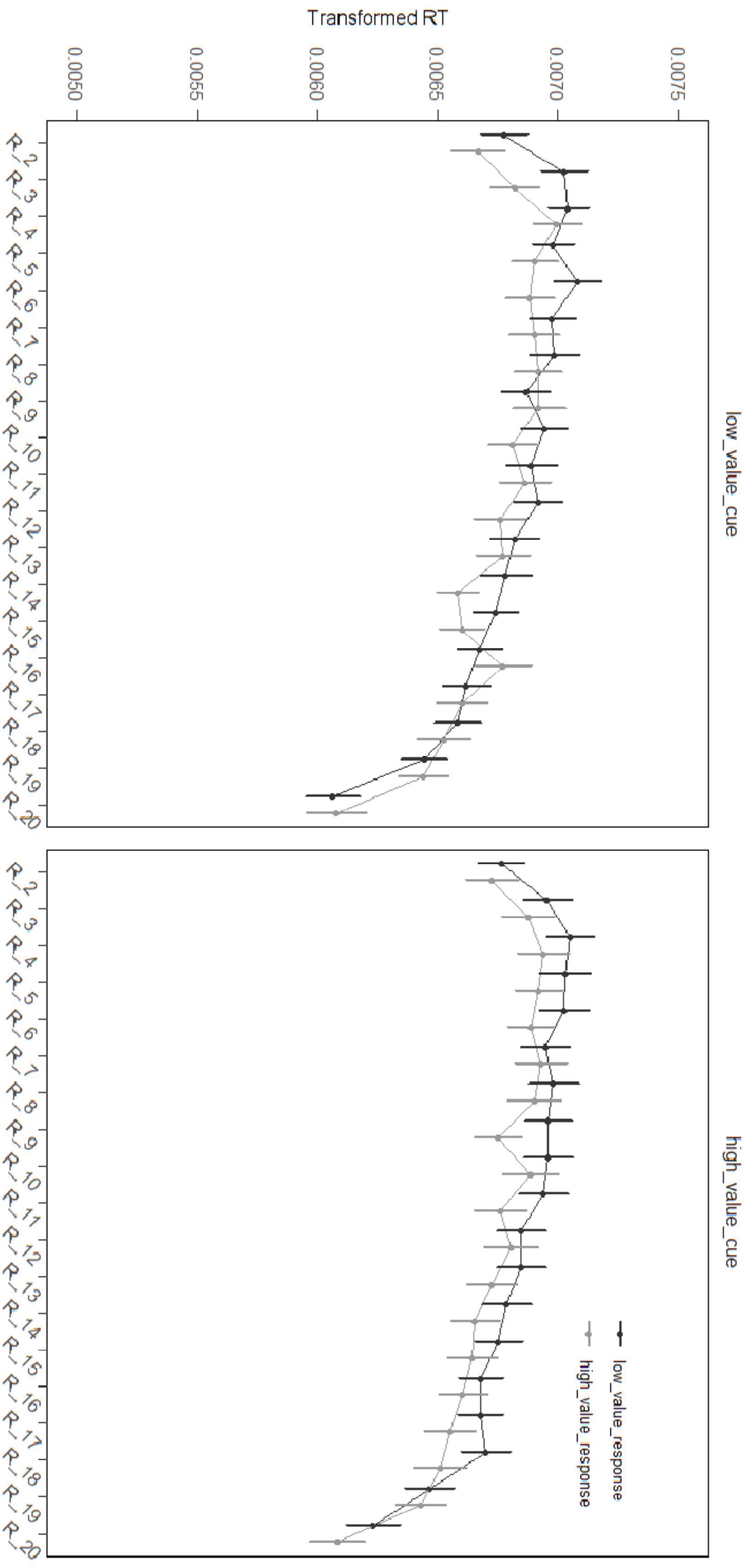

Figure 7, transformed RTs of remaining responses

EXTRA ANALYSES AND RESULTS OF THE MAIN EXPERIMENT (Reported in Chapter 5)

Instrumental training RTs

Descriptive analysis

Table 11: Descriptive analysis of instrumental training

response	RT_mean(F)	RT_sd (F)	RT_mean (R)	RT_sd(R)	ACC_mean	ACC_sd
low_value	698.294	371.839	199.499	229.683	0.980	0.049
high_value	700.178	423.755	202.001	232.944	0.988	0.035

Note: (F): first response in each trial. (R): remaining responses. We only measured accuracy for the first response.

Normality test

RT

Table 12: Normality test of instrumental training RTs

items	w_value	p_value
low_value (F)	0.721	<0.001
high_value (F)	0.642	<0.001
low_value (R)	0.525	<0.001
high_value (R)	0.547	<0.001

ACC

Table 13: Normality test of instrumental training ACC

items	w_value	p_value
low_value	0.463	<0.001
high_value	0.365	<0.001

RT and Acc tests

DVs shown in the RT and Acc Tests have been reciprocally transformed.

RT (first response)

The t-test indicates that no significant RT difference was observed between the low and high-value responses (t (102) = -0.17, p = .862) in the first response.

ACC

The t-test indicates that no significant ACC difference was observed between the low and high-value responses *(t* (102) = 1.64, *p* = .104).

Remaining responses

The 2 (high vs. low value) *19 (remaining responses) repeated measure ANOVA indicate that the main effect of responses outcome (*F* (1, 102) = 0.67, *p* = .415) and the two-way interaction effect (*F* (18, 1836) = 0.76, *p* = .746) were not significant. The main effect of remaining responses was significant (*F* (18, 1836) = 51.55, *p* = <.001, $\eta^2_p = 0.34$).

Exp 2 test phase RTs and ACC

Descriptive analysis (the first response)

Table 14: Descriptive analysis of test phase first response RTs and ACC

response	pav_cue	RT_mean	RT_sd	ACC_mean	ACC_sd
low_value	low_value	515.780	149.893	0.964	0.060
low_value	high_value	516.670	129.752	0.962	0.069
high_value	high_value	508.327	119.649	0.978	0.044
high_value	low_value	518.766	133.931	0.968	0.065

Descriptive analysis (remaining responses)

Table 15: Descriptive analysis of test phase remaining responses RTs

response	pav_cue	RT_mean	RT_sd
low_value	low_value	158.706	28.876
low_value	high_value	158.793	29.536
high_value	high_value	157.462	29.535
high_value	low_value	157.726	29.382

Normality test (the first response)

Table 16: Normality test of test phase first responses RTs

items	w_value	p_value
low_value_r&low_value_cue	0.665	<0.001
low_value_r&high_value_cue	0.745	<0.001
high_value_r&high_value_cue	0.796	<0.001
high_value_r&low_value_cue	0.753	<0.001

Normality test (rest of responses)

Table 17: Normality test of test phase remaining responses RTs

items	w_value	p_value
low_value_r&low_value_cue	0.958	<0.001
low_value_r&high_value_cue	0.946	0.002
high_value_r&high_value_cue	0.979	0.099
high_value_r&low_value_cue	0.983	0.210

Normality test (ACC)

Table 18: Normality test of test phase ACC

items	w_value	p_value
low_value_r&low_value_cue	0.625	<0.001
low_value_r&high_value_cue	0.606	<0.001
high_value_r&high_value_cue	0.520	<0.001
high_value_r&low_value_cue	0.558	<0.001

Accuracy of the first response

The accuracy pattern is presented in Figure 7. The planned contrast indicated that the predicted accuracy pattern was not significant (F (1, 102) = 3.49, p = .065). Although not significant, the pattern of accuracy shows that participants responded more accurately to the high-value outcome response than the low-value outcome response when encountering the high-value outcome cue, indicating that the RT effect cannot be easily explained by a speed-accuracy trade-off.

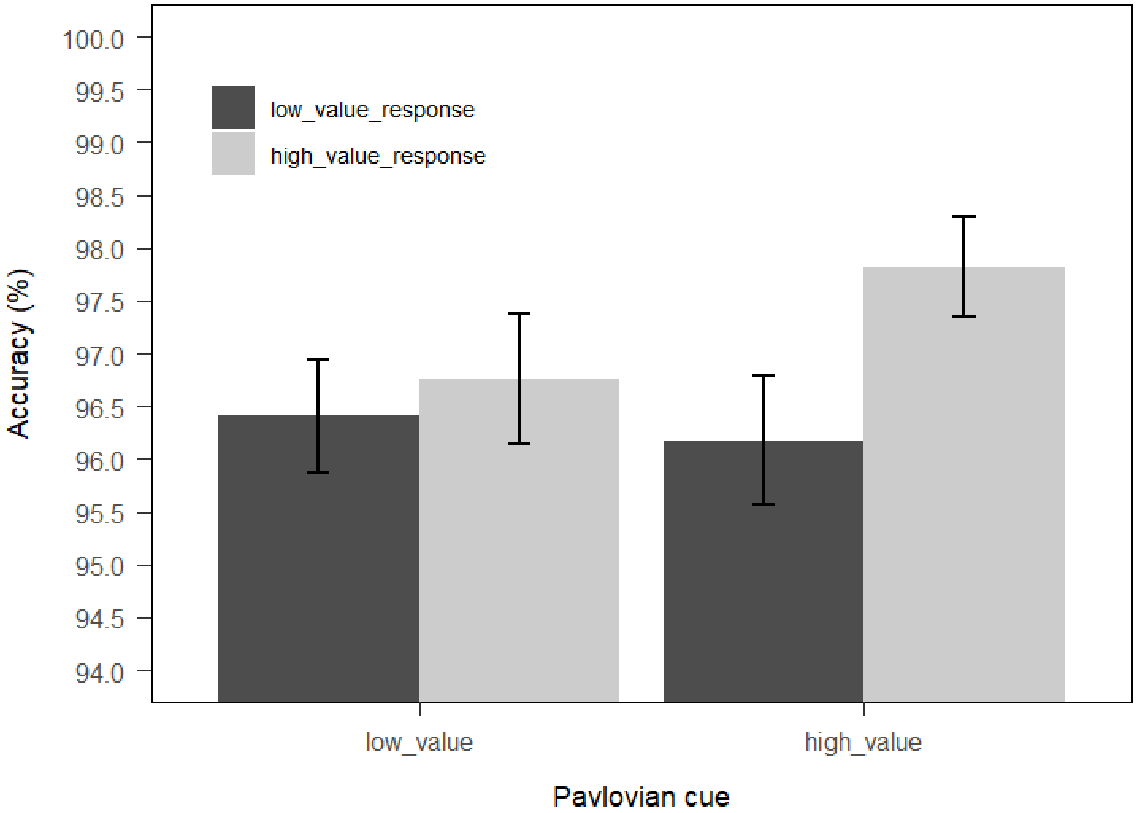

Figure 8. Accuracy pattern in the test phase. Error bars represent one standard error of the mean.

Supplementary plots for the test phase

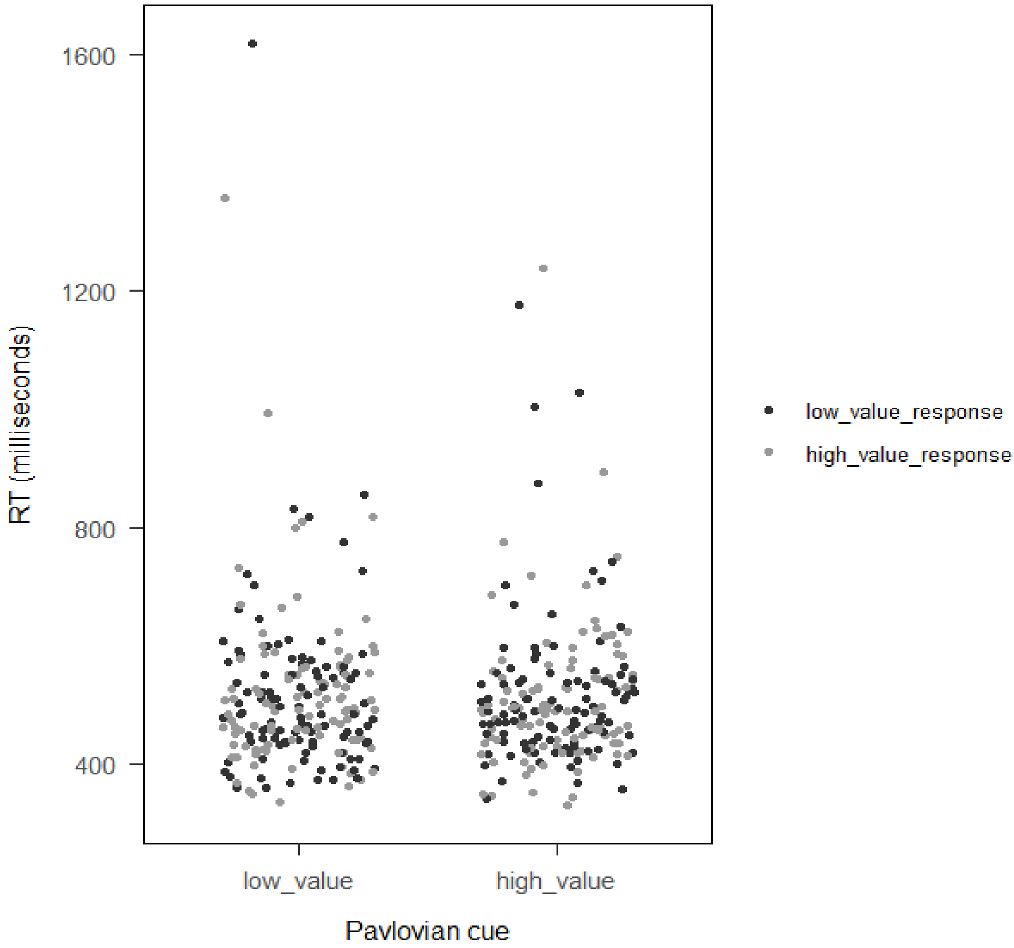

Figure 9, individual data points

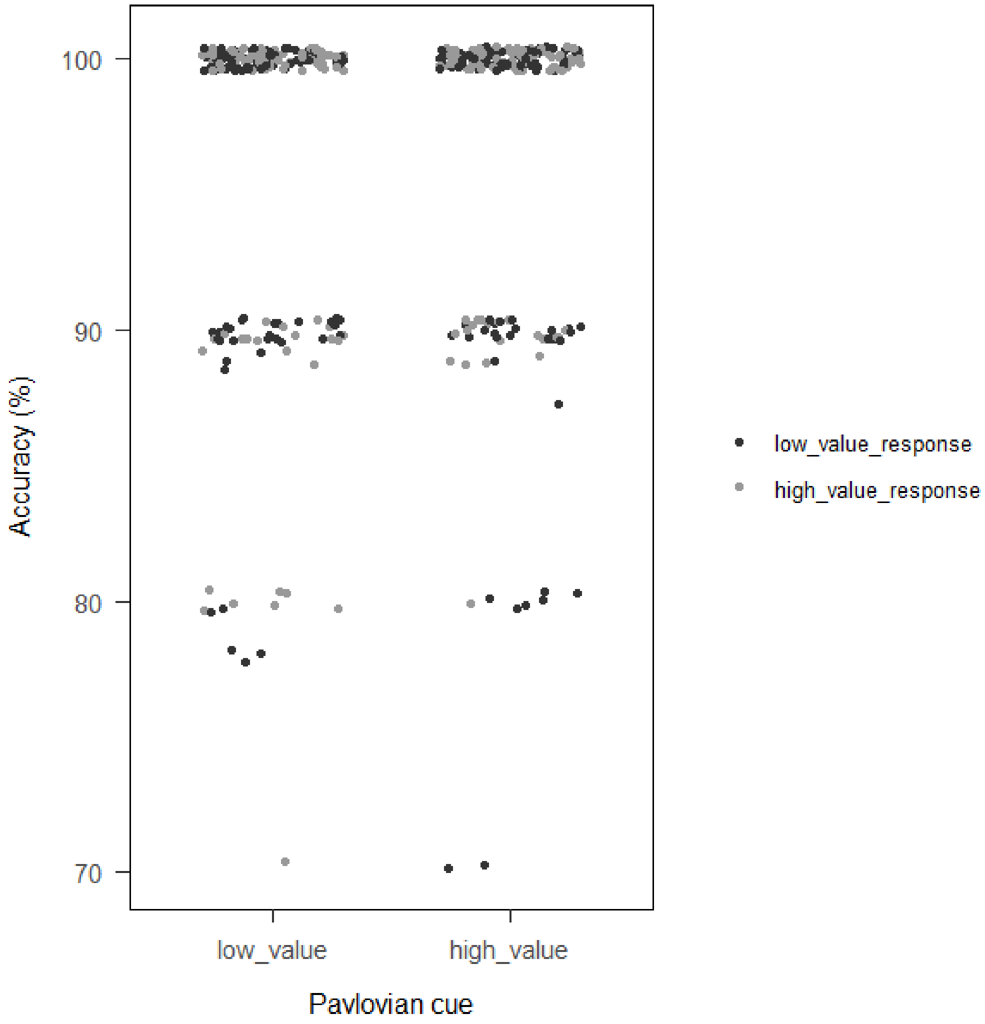

Figure 10, individuals data points ACC

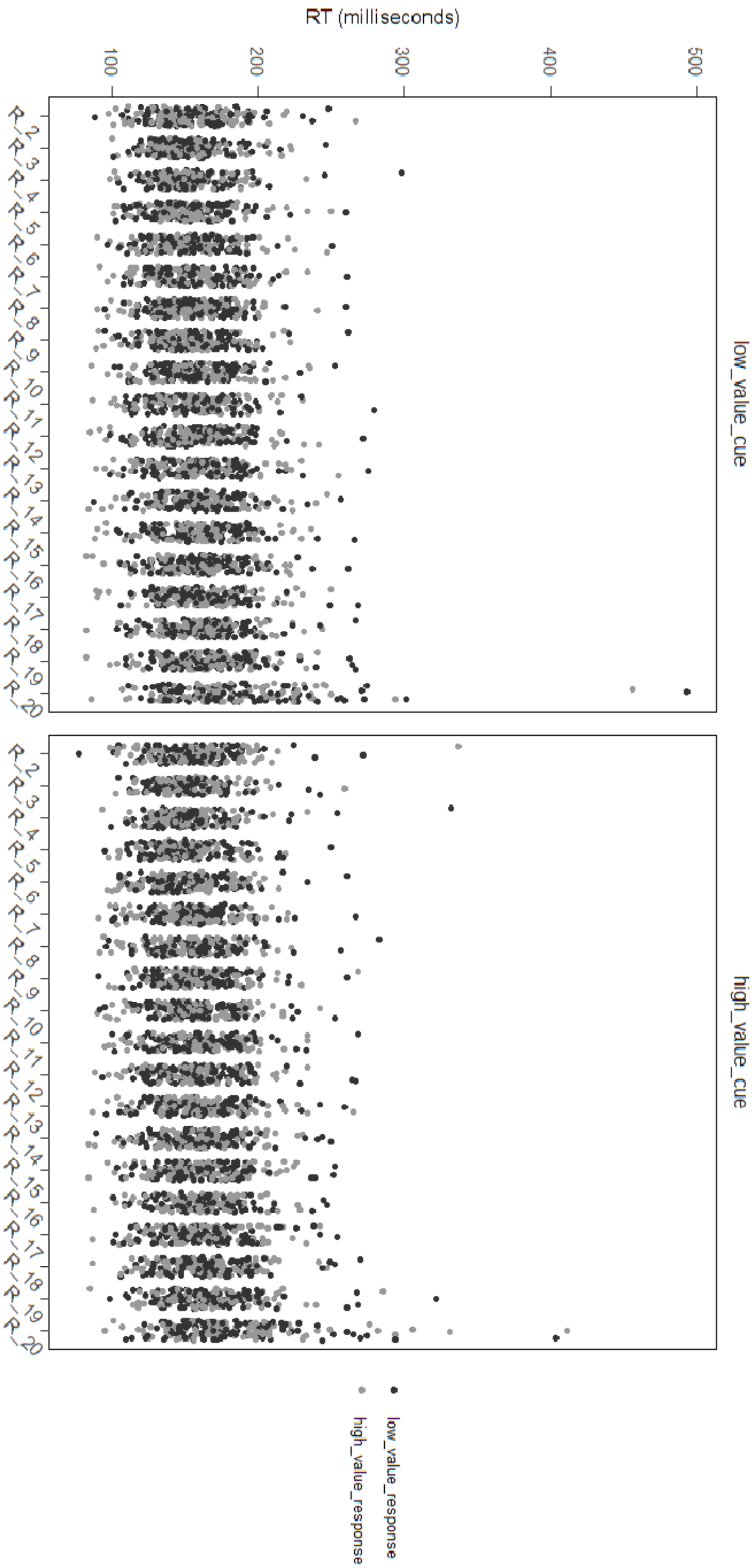

Figure 11, Individual data points remaining RTs

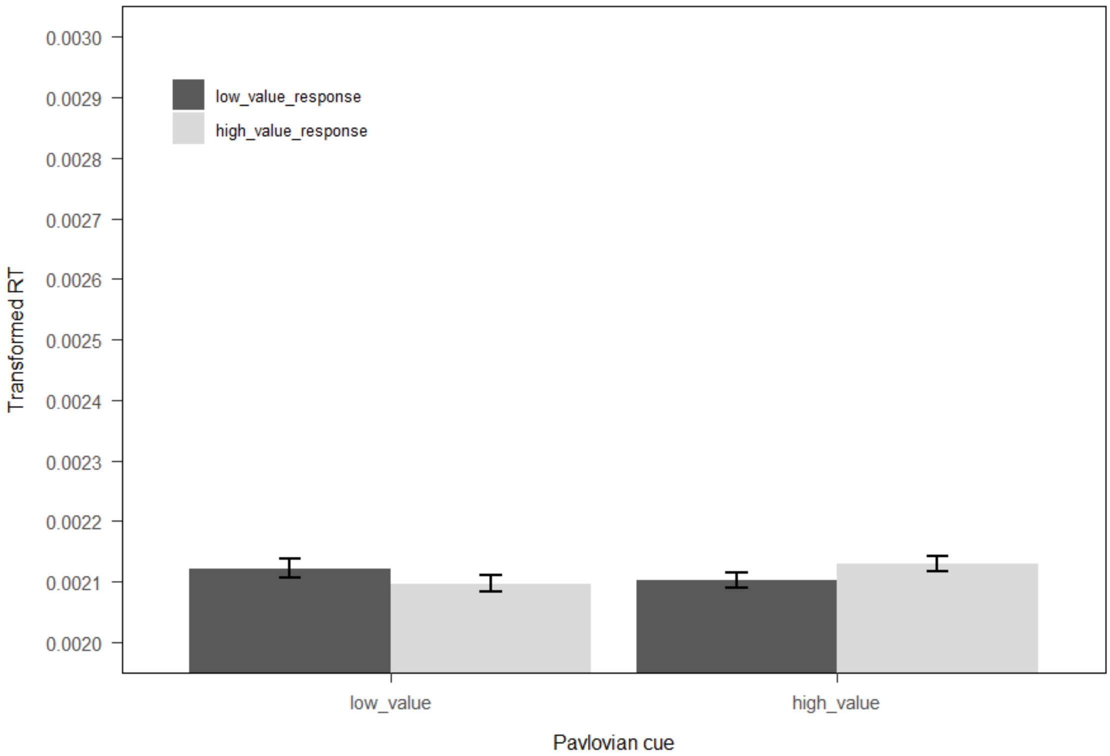

Figure 12, transformed first response RT

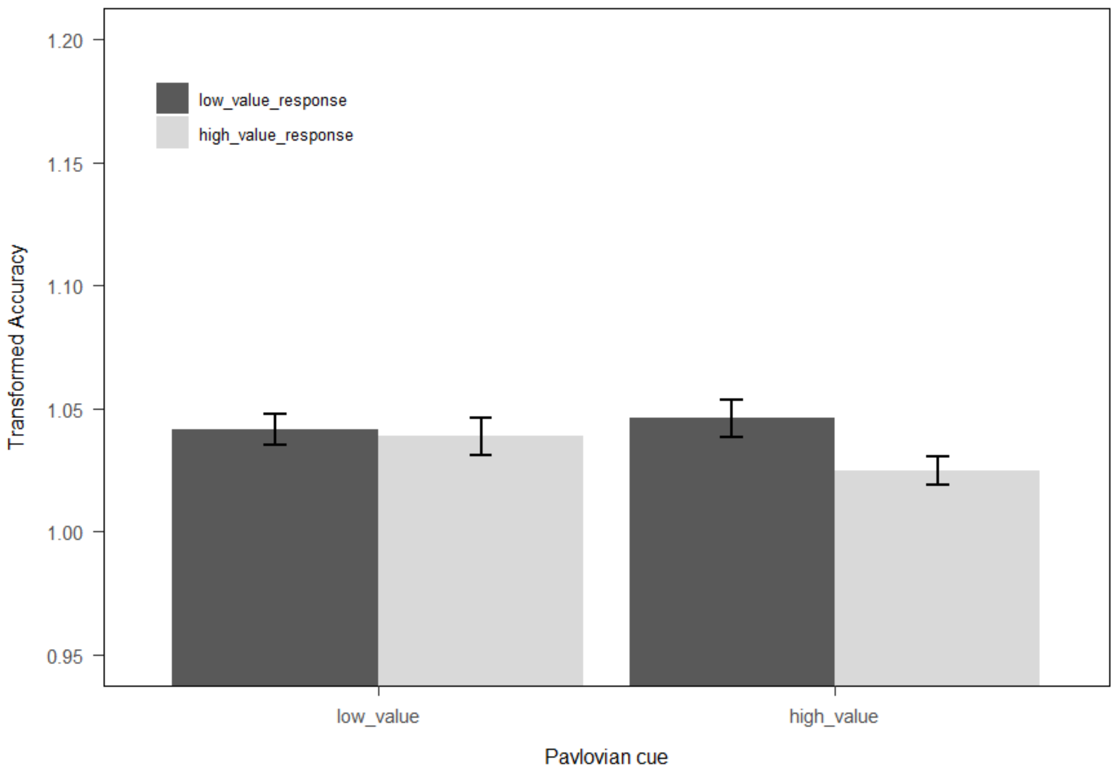

Figure 13, transformed ACC

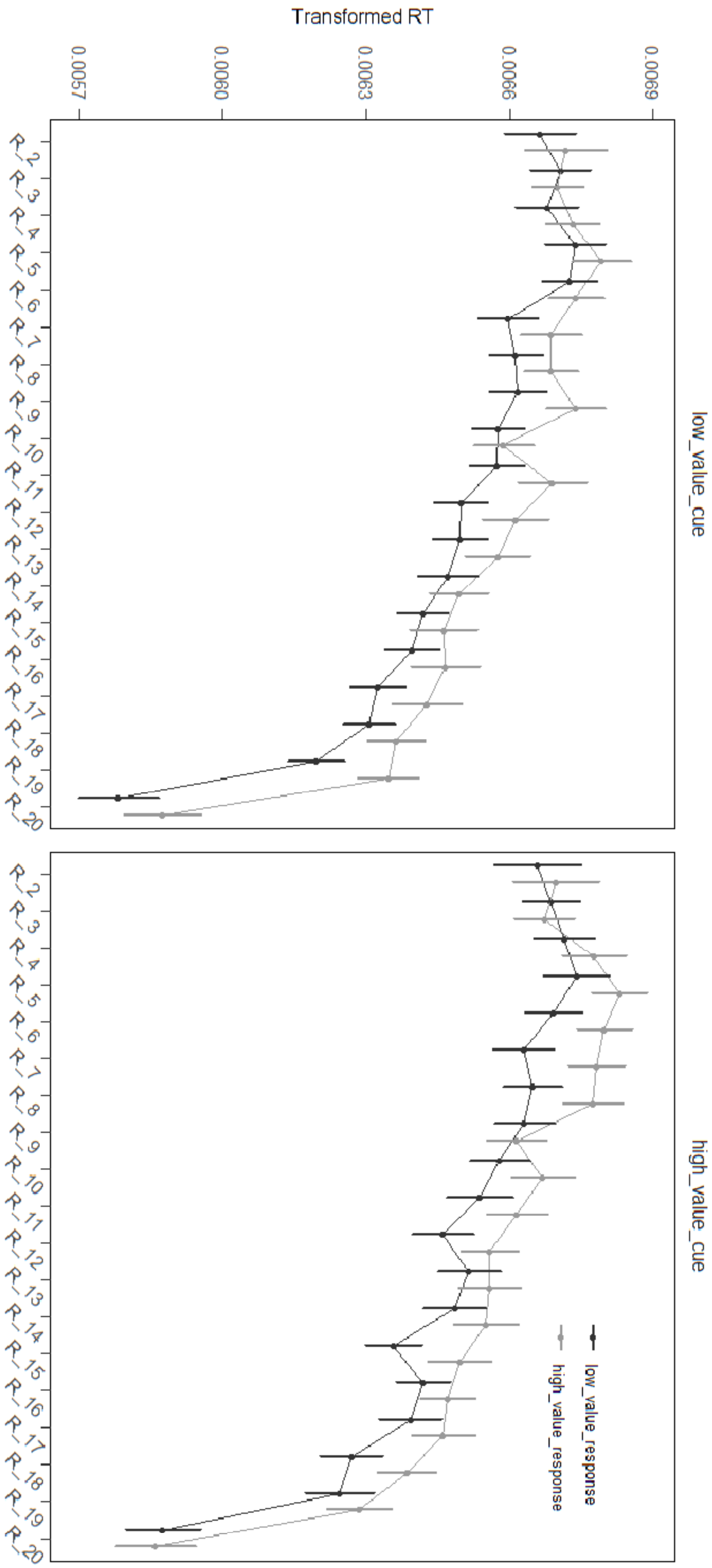

Figure 14, transformed RTs of remaining responses

Questionnaire of learning checks used in Experiment

Before ending the experiment, please answer the following questions.

what reward follows a 'moon'

a 5 cents coin

a 20 cents coin

What reward follows a 'star'

a 5 cents coin

a 20 cents coin

When you press the 'w' key multiple times, you could earn

a 5 cents coin

a 20 cents coin

When you press the 'o' key multiple times, you could earn

a 5 cents coin

a 20 cents coin

Questionnaire of task experiences used in Experiment

In the final phase of this experiment, you performed what was called the "hallway" task. In this task, you had to move a symbol (STAR or MOON or CLOUD) to the front of the screen by pressing multiple times on a LEFT key (letter 'w') or a RIGHT key (letter 'o'). The next questions are about this task.

Please, answer the following questions by entering the number that fits best with your answer.

How motivated were you to press the LEFT key ('w') multiple times in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to press the LEFT key ('w') multiple times in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How motivated were you to press the RIGHT key ('o’) multiple times in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to press the RIGHT key (‘o’) multiple times in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How motivated were you to collect the STAR in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to collect the STAR in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How motivated were you to collect the MOON in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to collect the MOON in the hallway task?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How motivated were you to press the LEFT key (‘w’) multiple times in order to move the STAR to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to press the LEFT key (‘w’) multiple times in order to move the STAR to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How motivated were you to press the LEFT key (‘w’) multiple times in order to move the MOON to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to press the LEFT key (‘w’) multiple times in order to move the MOON to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How motivated were you to press the RIGHT key ('o') multiple times in order to move the STAR to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to press the RIGHT key ('o') multiple times in order to move the STAR to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How motivated were you to press the RIGHT key ('o') multiple times in order to move the MOON to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

How much effort did you spend to press the RIGHT key ('o') multiple times in order to move the MOON to the front?

1(Not at all)-2-3-4-5-6-7(Very strongly)

Nederlandse Samenvatting

Nederlandse Samenvatting

Mensen voeren verschillende handelingen uit met als doel hun behoeften te vervullen en gewenste uitkomsten te krijgen. Dit is essentieel voor een verhoogd welzijn en kwaliteit van leven. Dit proces kan beïnvloed worden door omgevingsprikkels. Zo kan bijvoorbeeld de aanwezigheid van een koelkast ervoor zorgen dat iemand behoefte krijgt aan een koud drankje. Het openen van de koelkast leidt vervolgens tot het vervullen van deze behoefte en de gewenste uitkomst (namelijk, het koude drankje). Wanneer individuen signalen in hun omgeving waarnemen die geassocieerd worden met beloningen, kunnen ze gedrag vertonen dat leidt tot het gewenste resultaat. In de psychologie wordt dit gedrag ook wel gewoontegedrag genoemd. Gewoontes worden gevormd door het versterken van associaties tussen handelingen en situaties door middel van leren en herhaling. Als gevolg hiervan kan de stimulus (bijvoorbeeld de koelkast) het vermogen krijgen om het gedrag direct op te roepen (openen van de koelkast) wat impliceert dat beloningen een belangrijke rol spelen bij het ontstaan van gewoontepatronen.

Vroeger was het “habitual model of human cue-based behavior” dominant binnen de psychologie. Dit model veronderstelt dat er zowel lager-niveau gedrag (bijv. fietsen) als hoger-niveau gedrag (bijv. naar het werk gaan) bestaat. Recent onderzoek binnen cognitie en motivatie suggereert dat omgevingsprikkels ook indirect gedrag kunnen triggeren en stimuleren. Specifiek hebben omgevingsprikkels het vermogen om de verwachte uitkomst die geassocieerd wordt met een specifieke handeling te activeren, wat vervolgens de uitvoering van het gedrag vergemakkelijkt. Dit indirecte effect komt mogelijk voort uit ons cognitieve vermogen om op de uitkomsten van ons eigen handelingen en de beloningen die ze opleveren te anticiperen. Op basis van deze denkwijze wordt verondersteld dat de omgeving specifieke doelen kan oproepen die van invloed zijn op de uitvoering van gedrag en het bereiken van een bepaalde uitkomst. Het “habitual model of human cue-based behavior” model wordt veelvuldig gebruikt, met name binnen het veld van automatisch doelgericht gedrag. Onderzoeken gebaseerd op dit model tonen aan dat wanneer een woord (bijv. samenwerking) of een afbeelding (bijv. een rennende atleet) geassocieerd worden met een specifiek doel (bijv. helpen of winnen), deelnemers over het algemeen beter presteren in taken die verband houden met dat doel (bijv. een taak waarin ze iemand kunnen helpen om te winnen). Belangrijker nog is dat dit onderzoek laat zien hoe doelen met sociale betekenis, zoals presteren, helpen, en zelfs geld verdienen, getriggerd kunnen worden door omgevingsprikkels en mensen motiveren om acties te ondernemen die in lijn zijn met die doelen.

Niettemin wordt onderzoek naar de invloed van de omgeving op doelgericht gedrag bemoeilijkt door het ontbreken van robuuste methoden en empirie. Met name in het veld van automatisch doelgericht gedrag is het noodzakelijk om een duidelijk onderscheid te maken tussen gedrag dat direct geactiveerd wordt door prikkels en gedrag dat gemedieerd wordt door representaties van gewenste uitkomsten. Bovendien zijn de omgevingsprikkels die in deze studies gebruikt worden, vaak geassocieerd met zowel het doel als de instrumentele handelingen die ze in het dagelijks leven veroorzaken. Daardoor is het moeilijk om onderscheid te maken tussen de directe en indirecte effecten van prikkels op gedrag.

Om dit probleem aan te pakken, is in deze thesis gebruikgemaakt van het Pavlovian-to-Instrumental Transfer (PIT) paradigma om systematisch onderzoek te doen naar doelgericht gedrag op basis van prikkels; door gecued gedrag te vergelijken met hoogwaardige versus laagwaardige uitkomsten. Dit paradigma stelt ons in staat om actie-uitkomstleren te onderscheiden van stimulus-uitkomstleren, wat betekent dat de prikkel alleen indirect geassocieerd wordt met handelingen die leiden tot dezelfde uitkomsten. Hierdoor kan elk faciliterend effect van prikkels alleen toegeschreven worden aan het indirecte effect van uitkomstrepresentaties. Belangrijker nog is dat we dergelijke effecten onderzocht hebben op doelen met sociale betekenis (bijv. pro sociale doelen) en welk stadium van gedrag (d.w.z. actie-initiatie en actie-persistentie) beïnvloed kan worden door zulke processen.

De resultaten laten zien dat prikkels die voorspellend zijn voor zowel lage als hoogwaardige uitkomsten instrumentele reacties stimuleren wanneer de prikkel en reactie dezelfde uitkomst delen. Bovendien zijn de effecten sterker voor hoogwaardige uitkomsten, wat wijst op een waarde gebaseerd specifiek PIT-effect. Voor doelgerichtheid op hoog niveau hebben we vastgesteld dat een prikkel die voorspellend is voor uitkomsten die het individu ten goede komen instrumentele reacties vergemakkelijkt, terwijl het specifieke PIT-effect voor pro sociale uitkomsten alleen optreedt wanneer deelnemers de vrijheid hebben om te kiezen aan welke pro sociale uitkomsten ze willen bijdragen. Daarnaast hebben we ook de invloed van multifunctionele uitkomsten op het PIT-effect onderzocht. De resultaten tonen aan dat prikkels die geassocieerd zijn met multifunctionele beloningen de bijbehorende handelingen vergemakkelijken, terwijl prikkels die geassocieerd zijn met beloningen die maar één functie hebben dat niet doen. Bovendien hebben we het effect van prikkels op motivatie en doelgericht gedrag onderzocht. De bevindingen laten zien dat deelnemers sneller reageerden op prikkels met een hoge waarde. Dit effect werd echter alleen gevonden bij actie-initiatie en vertaalde zich niet in persistentie van de actie in de loop van de tijd.

Al met al werpt dit onderzoek licht op hoe omgevingsprikkels doelgericht gedrag kunnen beïnvloeden. Door de verschillende aspecten van doelgerichtheid en gedragsfasen te onderzoeken, dragen deze bevindingen bij aan ons begrip van de complexe interactie tussen omgevingsprikkels en doelen. Dit kan van belang zijn bij het ontwikkelen van interventies en strategieën om gewenst gedrag te bevorderen en ongewenst gedrag te verminderen, zowel op individueel als maatschappelijk niveau.

Acknowledgments

Acknowledgments

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A special acknowledgment goes to the members (and ex-members) of the Goallab, Chris, Manuel, Samantha, Yuru (玉茹), Myrthel, Dan (丹), Nil, Josi, Lurk, Baptist, Ruud H and UU Ph.D. fellows Tianchang (天昶), Wenrui (文蕊), Peikai (培凯), Chenhao (晨昊), Ilona, Piet, and Larisa. The time I spent with you all has been filled with collaboration and intellectual stimulation. The lively discussions, exchange of ideas, and shared experiences within our research group have been truly enriching. I am grateful for the friendships we have formed and the wonderful memories we have created together.

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I would like to end this acknowledgment with my favorite lyrics from one of my favorite bands (Good Charlotte): *Like soldiers, march on, if we can make it through tonight, we'll see the sun. March on. March on*!

Kaiyang (Kevin)

21st June 2023

Curriculum Vitae

Curriculum Vitae

Kaiyang (Kevin) Qin, born on November 27, 1991, in Huji, a small town in Hubei province, China, initially aspired to become a psychologist. After completing the Gaokao (The National College Entrance Examination), he embarked on his journey in psychology. In 2014, he earned his bachelor's degree in psychology from Hubei Normal University, and his passion for the field led him to pursue a master's degree in psychology at Southwest University (China). Following the completion of his master's degree in 2017, he commenced his Ph.D. project at Utrecht University under the supervision of Dr. Hans Marien, Dr. Ruud Custers, and Prof. Henk Aarts. As he delved into his Ph.D. research, he developed a keen interest in data science and programming and gradually acquired expertise in these areas. In 2022, Kevin secured a postdoctoral position at ASCoR, the University of Amsterdam, where he is currently engaged in a project focused on mapping the digital food environment. This opportunity enables him to continue his research and contribute to the field while exploring the intersection of social science, data science, and programming.

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