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Understanding and Motivating Human Control

Outcome and Reward Information in Action

Begrijpen en motiveren van menselijke controle

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(met een samenvatting in het Nederlands)

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Table of contents

Chapter 1

Introduction

People engage in many different tasks and activities during the course of a day. For most of these activities a considerable amount of effort is required to initiate, persist and complete them, such as using the bicycle to commute to one’s office, working through a list of fresh food at the grocery store to make a nice dinner for friends, and exercising at the gym to stay healthy or in good shape. An increase in effort suggests the involvement of some kind of control process, because it points to the fact that obstacles interfere and need to be overcome to reach the desired outcome (Kahneman, 1973; Strack & Deutsch, 2004). A habitual car-user may need to overcome the response to take the car instead of the bicycle as a mode of transport, or a person on a diet might need to resist the temptation to buy unhealthy snacks that are not on the list for the dinner with friends. Whereas this mobilization of effort enhances the likelihood of bringing us closer to the outcome, we also know that they come at a cost. So, people are more likely to mobilize effort for outcomes that are worth the cost (Brehm & Self, 1989). In addition, research suggests that goals are more likely to be pursued and reached when they are considered as outcomes of actions and desirable to attain (Fishbach & Ferguson, 2007; Gollwitzer & Moskowitz, 1996). Effective control of goal-directed behavior then, seems to depend on the way people cognitively represent their behavior and on the motivation to control their behavior.

This thesis deals with this issue. Specifically, I aim to address and investigate the potential building blocks of the motivation and control of goal-directed behavior. Most cognitive theories on decision making and goal-directed behavior suggest that goals and the level of motivation to control behavior is a function of some sort of expectancy-value principle, in which the individual makes a thoughtful analysis about the likelihood of the occurrence of an outcome as a result of action, and the value or desirability of that outcome (Eccles & Wigfield, 2002). Outcomes that are desirable and feasible to attain are more likely to be set as goals and motivate people to mobilize effort to control their behavior and to attain them (Locke & Latham, 2002).

The expectancy-value approach to understand the emergence of goal-directed behavior has taught us a lot about the way people act as agents in reflecting on, and computing action-relevant information into a meaningful course of action and to control their behavior accordingly. However, recent work has started to approach this matter from a more mechanistic view by suggesting that the motivation and control of goal-directed behavior is a kind of self-emergent property; a property according to which goal-directed behavior is considered to arise out of a combination of relatively simple processes operating on specific information (Braver & Cohen, 2000; Custers & Aarts, 2010; Hazy, Frank, & O'Reilly, 2007; Postle, 2006). Motivation and control of goal-directed behavior may simply be a property of the human mind that emerges from the brain's capacity to compute the magnitude of desirability and feasibility information, and to transform this information into a desired outcome or goal without an agent commanding and directing these computations. The underlying mechanism might thus comprise a combination of basic processes that produce the property to act in a goal-directed way. In line with such a mechanistic view, I address the question of how the self-emergent process of motivated goal-directed behavior may look like and can be modeled to understand how goals might be formed and motivate the control of goal-directed behavior.

To examine this, the present thesis departs from the assumption that the emergence of goal-directed behavior involves two basic features.

On the one hand, goal-directed actions are learned and represented in terms of their outcomes (Elsner & Hommel, 2001). For example, a person may learn to push a specific button to turn on the light. Hence, activating thoughts about turning on the light (previously served as an outcome) has the potential to select and control the action of pushing the button. On the other hand, motivation to attain the outcome arises from the incentive or rewarding value of the outcome (Shizgal, 1999). Such incentive or rewarding value may refer to goals or outcomes itself, such as earning monetary rewards, or may result from information in the environment that accompanies a goal or outcome, such as a nice remark by another person or a picture that elicits positive affect. For example, when turning on the light has been learned to be a pleasant event, people are likely to put more effort in pushing the corresponding button. Hence, outcomes that are associated with positive reward signals are more likely to cause the individual to mobilize effort and to actually control behavior. Moreover, such mobilization of effort takes into account the principle of conservation, such that the reward signal determines whether expenditure is actually worth the investment (Wright, 2008).

However, both features have been investigated in two lines of literature that so far have led separate lives. First, one line of literature is mainly concerned with the action-outcome learning principle, according to which actions are represented in terms of their outcomes. In order to be able to act voluntarily and to select the proper action a person first has to acquire knowledge about action-outcome relationships (Shin, Proctor, & Capaldi, 2010). The second line of literature mainly considers the role of positive reward signals in human control of action. It is well documented in this literature that the way goals control behavior is dependent on motivation, and that motivational significance is acquired through positive reward signals (Chiew & Braver, 2011).

Chapter 2 of this thesis integrates both lines of literature and offers a theoretical perspective on how outcome information and reward information may interact to modulate control processes of human goal-directed behavior. It is proposed that reward signals accompanying the activation of action-outcome information signify the value of the outcome and facilitate the recruitment of control resources (effort) in situations where behavior needs to be maintained or adapted to attain the desired outcome.

Based on this theoretical analysis, the three subsequent empirical chapters test three aspects that are good candidates to assess the self-emergent property of goal-directed behavior. Specifically, in Chapter 3 it is investigated how reward information interacts with control demands to determine the amount of effort mobilization in goal-directed action. Effort mobilization is often considered to be the result of a trade-off, in which the individual responds to explicit information about the difficulty or demands of a task and invest more effort when the reward value of the task justifies the cost of spending the effort (Brehm & Self, 1989). In other words, effort is mobilized according to a principle of resource conservation. Chapter 3 examines whether information of demands also modulates the mobilization of effort in a reward-driven task when these demands are not explicitly cued and are unpredictable during task performance. Such an effect would suggest that the control of goal-directed behavior results from a self-emergent process in which demand and reward information interact.

Chapter 4 considers effort mobilization in terms of ease of switching from one action to another. Goal-directed behavior often needs to be adapted according to changes in the environment, such that an ongoing course of action needs to be switched to another course of action in order to attain the outcome. This operation of switching is a control process that requires effort, meaning that reward information can modulate the speed of switching by interacting with the outcome information. Chapter 4 investigates how reward information and outcome information interact in controlling goal-directed behavior. In this chapter, the interaction between reward and outcome information is manipulated in such a way that the process of switching and its modulation by reward should emerge by itself (i.e., without explicit instruction or knowledge about the combined operation of both types of processes), again examining the self-emergent property of motivated goal-directed behavior in terms of an interactive process between outcome and reward information.

In Chapter 4 it is investigated how the interaction between reward and outcome information changes ongoing goal-directed behavior (i.e., switching a course of action). However it does not provide evidence for whether this interactive function of reward and outcome information also occurs in the context of action-outcome learning, and as a result increases the motivation to attain the outcome in a goal-directed fashion (i.e., by mobilizing effort to obtain the outcome. Therefore, Chapter 5 pushes this idea one step further by investigating whether motivated goal-directed behavior self-emerges when action-outcome learning is combined with the processing of reward information. In the studies discussed in this chapter, participants first acquired knowledge about action-outcome relationships in a rewarding context or not to test whether this interaction would lead them to initiate and engage in motivated goal-directed behavior in a task that measured goal-directed aspects of behavior, but did not explicitly instruct participants to do so. This test would indeed suggest that motivated goal-directed behavior can originate from a self-emergent process.

To examine the aspects of self-emergent goal-directed behavior described above I will make use of several experimental methods inspired by research on reward signal processing (e.g., Pessoa & Engelmann, 2010), evaluative conditioning (e.g., De Houwer, Thomas, & Bayens, 2001), task-switching and control (e.g., Meiran, 2010), physical effort mobilization (e.g., Bijleveld, Custers, & Aarts, 2012) and action-effect binding (Hommel & Elsner, 2009). Below I will introduce the empirical chapters in more detail.

Effects of reward information on effortful control under uncued task demands

Reward-driven modulation of human control is highly adaptive, because it justifies the allocation of the limited attentional resources in the most conserving way (Pessoa, 2009). Resource allocation is thus guided by a principle of conservation such that effort will only be expended if it can be compensated by a reward in the end. According to motivation intensity theory the need for effort is determined by the difficulty of activity that must be carried out to attain desired outcomes, such as monetary rewards (Brehm & Self, 1989; Gendolla, Wright, & Richter, 2011). Thus as long as effort allocation is worthwhile it will correspond with the assessed difficulty and control demands of the task. However, whereas earlier research on rewards and effort allocation mainly informs participants explicitly about task difficulty, in real life it is not always possible to know in advance how demanding it will be to maintain and adapt behavior successfully. This raises the question of how rewards modulate effortful control when demands are not clear.

In Chapter 3 this idea is addressed using a modality shift paradigm in which task demand (i.e., switching of attention) is not explicitly cued beforehand (Turatto, Benso, Galfano, & Umiltá, 2002; Rodway, 2005). Specifically, participants were instructed to respond to visual or auditory targets as fast as possible. Immediately before presentation of these targets either a preparatory stimulus in the same modality as the target (ipsimodal trials, e.g., visual-visual), or a preparatory stimulus in a different modality (crossmodal trials, e.g., visual-auditory) was presented. The latter type of trials requires more effort (i.e., are more demanding) to respond to accurately and quickly than the former type, because participants have to switch their attention from the visual modality to the auditory modality. It was tested whether participants would respond faster when a reward was at stake during switch trials, but that there would be no speeded responding during rewarded trials that did not require an attentional switch. It was found that reward signals indeed specifically reduced switch costs in an instrumental way, even in contexts that are ambiguous about task demands. In sum, reward information interacts efficiently with control demands to manage and conserve control resources even when demands are unpredictable.

Effects of levels of behavior representations and reward information on effortful control

Chapter 3 suggests that reward information selectively causes individuals to mobilize effort to control goal-directed behavior in a task switching context. In Chapter 4 I will examine how task goal information interacts with reward information in mobilizing effort and controlling behavior. To examine this I take into account the notion that task goals or goal-directed behaviors in general are hierarchically structured in a format of goals and means, so that instrumental actions are selected in a top-down fashion (Botvinick, 2008; Kruglanski et al., 2002; Vallacher & Wegner, 1987). This opens up the possibility that the level at which a task or behavior is represented (i.e., goals or means), may have implications for how reward signals motivate and control behavior.

In Chapter 4 the interplay between reward information and outcome information is examined in more detail. It was investigated whether the interaction between positive reward signals (i.e., positively valenced pictures) with outcome information translates into control for goal-directed behavior. Participants had to repeatedly perform a specific action (e.g., pushing a green button) to attain a particular outcome (i.e., turning on the light). During this learning phase participants were cued in terms of the outcome (a message telling them to turn on the light) or were cued in terms of the action (a message telling them to push the green button). In addition, these cues were either accompanied by a neutral picture or a positive picture, serving as a reward signal. At some point the trained action was replaced by a new action (e.g., pushing a blue button) to attain the same outcome. When the outcome cue was learned to be associated with a positive reward signal participants became more flexible in that they were able to execute the new action more easily in terms of speed of responding. However, when the trained action itself was learned to be associated with a positive reward signal participants became more rigid and were less able to quickly execute the new action.

These findings suggest that being able to swiftly switch the course of action to obtain an outcome is dependent on how the task is represented and whether this was co-activated with reward signals. That is, the impact of reward signals on motivated goal-directed behavior seems to be dependent on whether behavior is represented in terms of actions or in terms of outcomes.

The role of reward information in action-outcome learning

According to the findings of Chapter 4 positive reward signals should increase control when they accompany outcome information. As stated previously, outcome information is defined here as information that follows an action rather than preceding it (Hommel, 2013). Accordingly, an accompanying positive reward signal can cause people to engage in controlled behavior when the information directing behavior is conceived of as an outcome of action.

In Chapter 5 this idea was tested with a paradigm that simulates the process by which people learn to represent their behavior in terms of outcomes. Specifically, participants had to execute an action (pressing a key) that was either preceded or followed by an object on the computer-screen (e.g., the word “scissors”). The object was accompanied by a neutral or positive reward signal by presenting a spoken word through headphones (e.g., the word “with” or “nice”). Thus, the object was conceived of as an outcome of an action or not, and this outcome information was co-activated with a reward signal or not. After this learning phase, the motivation to control behavior was assessed by the way people responded to the object. It was found that people wanted to obtain the objects more eagerly (e.g., an increased amount of effort to obtain it) when they were conceived of as outcomes of actions and were paired with positive reward signals. In sum, these findings suggest that motivated control of goal-directed behavior can be induced when positive reward signals accompany the process of action-outcome learning.

Conclusions and Implications

In this thesis I have tried to investigate motivated goal-directed behavior from a self-emergent process perspective. This perspective supposes that motivation for goal-directed behavior can be the result of a pattern of relatively simple interactions between reward and outcome information. In this thesis I have examined three basic interactions to demonstrate the potential self-emergence of motivated goal-directed behavior.

In Chapter 3 it is shown that prospective monetary gains encourage people to invest effort and mobilize control processes for better task performance. Importantly, reward induced effort mobilization only occurred when task demands were high in terms of control processing, even when these control demands were not explicitly cued beforehand. In other words, this process of motivated control, which was governed by a principle of conservation, seems to follow a self-emergent property. Chapter 4 investigates how reward information and outcome information interact in controlling goal-directed behavior. In this chapter, it was examined how the interaction between reward and outcome information spontaneously influenced the way people controlled their goal-directed actions. In the experiments described in Chapter 5 participants first acquired knowledge about action-outcome relationships in a rewarding context or not, and it was shown that this produced motivated goal-directed behavior on its own accord. This finding again suggests that motivated goal-directed behavior can be the result of a self-emergent process.

Taken together, these three main findings fit well with recent mechanistic view on goal-directed behavior and offers insight into the potential building blocks that renders human action goal-directed. It is important to note that these building blocks are not essentially different from those proposed by other approaches to understand goal-directed behavior, such as the traditional expectancy-value approach. This approach also takes the value of an outcome into account to understand goal-directed behavior. Importantly, the traditional expectancy-value approach considers goal-directed behavior to result from people's ability to explicitly reflect on and compute the value of an outcome. The current thesis tries to offer a different perspective to understand how goal-directed behavior emerges and is maintained over time, and that answering this question could be facilitated by looking at specific interactions between specific types of information that have been argued to form the basis of motivated goal-directed behavior, such as information about rewards, outcomes, and demands.

Here I proposed and tested that these basic interactions can be used to predict effects that can be qualified in terms of motivated goal-directed behavior. Whether these effects are mediated by certain psychological mindsets, such as intentions or conscious deliberation, is still a matter of debate (Baumeister, Masicampo, & Vohs, 2011; Koch & Tsuchiya, 2007; Lau & Rosenthal, 2011; Winkielman & Schooler, 2008). However, the analysis in the current thesis cultivates the notion that these psychological mindsets do not necessarily have to be the starting-point to examine and predict how motivation and control of human goal-directed behavior may emerge.

However, it may be important and fruitful in future research to investigate how the mechanistic view differs from the expectancy-value approach and perhaps how they can be integrated to offer a fuller account for how humans are able to motivate and control their behavior towards future states or outcomes.

The present thesis may also have implications to further our understanding about issues of self-control. Self-control dilemmas are part of goal-directed behavior and are often conceptualized as internal conflicts between long term and short term benefits (Mischel, Cantor, & Feldman, 1996; Trope & Fishbach, 2000). In other words, people weigh the value of a short term outcome against that of a long term outcome and they do this on a regular basis. Moreover, people might be prone to more readily reflect on short than on long term outcomes, thereby bolstering the perceived feasibility and motivation to attain short-term outcomes (Trope & Liberman, 1998). Based on the expectancy-value principle, then, it might not be surprising that people often fail to resist and override motivationally salient and directly available outcomes that compete with longer term outcomes that are not likely to occur soon (Baumeister, Heatherton, & Tice, 1994).

The findings of the current thesis might offer a new perspective to explore how the ability for self-control can be elevated without intervening on the agent level. From a self-emergent process perspective, *self*-control can also refer to *auto*-control in the sense that control arises as an emergent property that is produced by a combination of basic mechanisms. Thus, studying the interactions between information about rewards, outcomes, and demands might provide new insights for understanding and improving self-control. Especially the finding that flexible control occurs when people process reward signals upon representing their behavior in terms of outcomes (e.g., goals) rather actions (e.g., means) might be an interesting starting point to explore a more mechanistic perspective on the matter. For example, it could be tested whether the interaction of outcome and reward information establishes a different pattern of self-control and how this may differ from a more conventional approach, according to which people are asked to reflect on the value of short or long term outcomes.

Furthermore, the research described in the present thesis could be used to explore new ways to improve people's self-control in many different settings. For example, this could comprise issues of self-control in the realm of health behavior, but also in the area of economic behavior where the (un)willingness to cooperate can be a challenge for society in general. After all, many of these self-control dilemmas may essentially boil down to issues of human functioning that address the question of whether and how action-outcome learning in a rewarding context may feed into the motivation and control of behavior.

Now that I have briefly introduced the research program of the present thesis, it is time to move to a more detailed level of report. Accordingly, apart from Chapter 2 the remaining part of the thesis describes the empirical work. The chapters in this thesis have been written separately and can be read independently of each other as a scientific journal article. This means that some overlap in content is possible across the chapters.

Chapter 2

Adaptive control of human action: The role of outcome representations and reward signals

Abstract

The present paper aims to advance the understanding of the control of human behavior by integrating two lines of literature that so far have led separate lives. First, one line of literature is concerned with the ideomotor principle of human behavior, according to which actions are represented in terms of their outcomes. The second line of literature mainly considers the role of reward signals in adaptive control. Here, we offer a combined perspective on how outcome representations and reward signals work together to modulate adaptive control processes. We propose that reward signals signify the value of outcome representations and facilitate the recruitment of control resources in situations where behavior needs to be maintained or adapted to attain the represented outcome. We discuss recent research demonstrating how adaptive control of goal-directed behavior may emerge when outcome representations are co-activated with positive reward signals.

This chapter is based on: Marien, H., Aarts, H., & Custers, R. (2013). Adaptive control of human action: The role of outcome representations and reward signals. Frontiers in Psychology, 4, 602.

Human goal-directed behavior is supported by a set of mental tools that tune action to dynamic environments. The question how this adaptive control process works has received a lot of attention in the literature (Morsella, Bargh, & Gollwitzer, 2009). Although there exist different conceptualizations, such as executive processes (Smith & Jonides, 1999), working memory operations (Baddeley, 2007) and cognitive control (Miller & Cohen, 2001), they share three basic components of control: active maintenance of goal-relevant information; inhibition of irrelevant information; and shifting of information (Miyake & Shah, 1999).

Most research on the control of human behavior considers the person as the agent of control (Bandura, 2001; Locke & Latham, 1990). People are assumed to control their behavior by setting goals, keeping them active in mind, and adapting their behavior when needed. More recent research adopts a mechanistic account by suggesting that adaptive control processes are self-emergent once a goal is activated (Braver & Cohen, 2000; Hazy, Frank, & O'Reilly, 2007; Postle, 2006). In line with this mechanistic account we take the activation of a goal as the starting point of our analysis, and address the question of how the self-emergent process may be modeled to understand how goals instantiate adaptive control.

Basically, two features are central to the control of goal-directed behavior. The first feature pertains to the notion that actions are represented in terms of outcomes. The second feature comprises the rewarding property or value of these represented outcomes. Research on ideomotor theory of action investigates the first feature by examining and explaining how action-effect knowledge is acquired and how outcome representations are implemented in action selection (Hommel, 2013). Research on the second feature investigates how rewarding or positive affective signals, such as positive mood (Aspinwall, 1998; van Wouwe, Band, & Ridderinkhof, 2011), monetary gains (Heitz, Schrock, Payne, & Engle, 2008; Müller et al., 2007), or positively valenced outcome information (Custers & Aarts, 2005; Gable & Harmon-Jones, 2008) influence perception and cognition in action control.

In essence, both features work in tandem to control behavior adaptively. Whereas outcome representations serve as reference points for perception and action (Carver & Scheier, 1982; Powers, 1973), accompanying positive reward signals assign value or utility to outcomes (Shizgal, 1999) and facilitate the recruitment of executive control processes (Locke & Braver, 2010). However, a theoretical and empirical analysis of the combined role of these features has largely been neglected in the literature. Here, we aim to integrate research on the ideomotor principle and research on the role of reward signals in action control.

The role of outcome representations in the control of behavior

Human goal-directed behavior is thought to result from the brain's capacity to predict and represent actions in terms of their outcomes (Suddendorf & Corballis, 2007). Activating an outcome representation prepares action in an offline fashion (i.e., planned ahead). However, engaging in goal-directed behavior requires knowledge about action-effect relationships. Action-effect learning has been extensively studied and provides an explanation for the emergence of outcome representations (Shin, Proctor, & Capaldi, 2010). Basically, a link between action and effect is formed when a consequence of a motor movement is observed and further strengthened if this effect occurs consistently. Because the link between action and effect is assumed to be bidirectional, this strengthened link can be used to produce a specific outcome. This is the ideomotor principle: activating an outcome representation readily selects the action (Hommel, Müsseler, Aschersleben, & Prinz , 2001).

According to this principle, multiple outcome representations can be associated with multiple actions (Hommel, 1996; Kunde, Hoffman & Zelman, 2002). This way, goal-directed behavior is structured around equifinality and multifinality sets. Multiple actions can thus serve one outcome or a single action can produce multiple outcomes, rendering goal-directed behavior adaptive (Kruglanski et al., 2002).

Initially the ideomotor principle explains action selection on a sensorimotor level. However, human behavior is more complex and involves goals that are further removed from direct motor activation. It can be suggested, though, that goal-directed behavior emerges from simple movement goals to complex social goals that are accessed in different contexts by the same mechanisms underlying action-effect learning (Maturana & Varela, 1987). We first learn to orchestrate our motor movements before we can effectively hit a light switch and illuminate a dark room. Eventually certain learned patterns of motor movements become associated with new observable outcomes in terms of sensory/perceptual and semantic/cognitive codes (Aarts & Veling, 2009; Kray, Eenshuistra, Kerstner, Weidema, & Hommel, 2006; Pulvermüller, 2005; Lindemann , Stenneken, van Schie, & Bekkering, 2006). Indeed, it has been demonstrated that sensory-motor goal representations (acquired in goal-directed motor tasks) generalize to abstract features of outcomes, such that outcome representations can become socially meaningful (Beckers, De Houwer, & Eelen, 2002).

People rely on these outcome representations during action selection and execution. In cybernetic models of action control outcome representations serve as reference points (Adams, 1971). When an action produces an outcome not matching the pre-activated outcome representation, an action-related error signal is produced (Carter et al., 1998). Control is then necessary and should subsequently result in switching to a new course of action and inhibiting the old one. Active maintenance of the outcome representation thus often operates in concert with other adaptive control processes to attain the outcome.

The role of reward signals in control

Ideomotor theorizing provides a parsimonious framework to understand how action-effect knowledge is acquired and how outcome representations are involved in the selection of action. However, it does not include specific predictions about when and how outcome representations gain control over behavior. There is a vast literature that does examine the emergence of adaptive control from an affective-motivational perspective.

First of all, there is research on the role of positive mood or emotion in cognitive control (Ashby, Isen, & Turken, 1999; Fredrickson, 2004). This literature suggests that positive affect can broaden cognition (e.g., making people more creative) or funnel cognition (e.g., by focusing on local stimuli). Secondly, there is literature showing effects of prospective monetary gains on control processing such that effortful behavior can be boosted or strategically implemented (Bijleveld, Custers, & Aarts, 2012). Finally, the positive valence of outcome representations (acquired through evaluative conditioning procedures) can enhance effortful control in tasks generating the outcome (Custers & Aarts, 2010). These different lines of research suggest that positive affect, monetary gains and positive outcome representations serve as a general reward signal that acts as a common currency for modulating adaptive control (Shizgal & Connovor, 1996), which either results in increased flexibility or more focused processing (Aston-Jones & Cohen, 2005). It remains unclear how the affective-motivational perspective deals with the question of when flexible or focused processing dominates. However, it is assumed that adaptive control processes originate from subcortical output releases of dopamine in the PFC, which is associated with the processing of general reward signals (Aarts, van Holstein, & Cools, 2011; Chiew & Braver, 2011).

From this affective-motivational perspective, reward signals have been found to play a crucial role in each of the three basic components of adaptive control. Reward signals have been shown to (1) cause active maintenance of task relevant information and outcomes (Zedelius, Veling, & Aarts, 2011); (2) facilitate the inhibition of task-irrelevant information (Veling & Aarts, 2010); and (3) reduce switch costs in task-switching paradigms (Dreisbach & Goshke, 2004). These findings indicate the close relationship between adaptive control of human action and the processing of reward signals.

Reward-driven modulation of executive control is highly adaptive, because it justifies the allocation of limited cognitive resources (Pessoa, 2009). Resource allocation is guided by a principle of conservation such that effort will be expended only if it can be compensated by a significant benefit in the end (Brehm & Self, 1989; Gendolla, Wright, & Richter, 2011). Reward signals thus ensure the recruitment of adaptive control processes when behavioral demands are imposed by environmental changes. Indeed, there are several studies that show how task demands and task incentives interact in producing effort intensity (Bijleveld, Custers, & Aarts, 2009; Silvestrini & Gendolla, 2013). In this research the conditions of demand are often explicitly communicated and it is shown that individuals invest effort only when the goal is attainable (i.e., moderately high demands) and valuable rewards are at stake. Thus, people seem to make trade-offs by weighing explicit information of reward value and demands. This raises the question of whether demand information needs to be explicit or whether such trade-offs also occur in contexts where differences in demands are less clear.

In a recent line of research we addressed this question using a modality shift paradigm (Marien, Aarts, & Custers, in preparation-a). Participants were instructed to respond to visual or auditory targets as fast as possible. Immediately before presentation of these targets we either presented a preparatory stimulus in the same modality as the target (ipsimodal trials, e.g., visual-visual), or a preparatory stimulus in a different modality (crossmodal trials, e.g., visual-auditory). The latter type of trials requires more resources (i.e., are more demanding) to respond to than the former type, because participants have to switch their prepared visual modality to the auditory modality. This typically results in a delayed response time caused by a modality switch cost, especially when this switch cannot be anticipated (Turatto, Benso, Galfano, & Umiltá, 2002). On half of the trials participants were presented with a 5 eurocents coin which they could earn; on other trials this reward signal of the coin was absent. Importantly, the preparatory stimuli were not predictive of whether a switch would occur or not. As expected, participants responded significantly faster when a reward was at stake during crossmodal trials, but there was no speeded responding during rewarded ipsimodal trials. Furthermore, the absence of the latter effect could not be explained by physical limits of speed of responding. Reward signals thus specifically reduce switch costs in an instrumental way, even in contexts that are ambiguous about task demands.

However, in most research on reward signals and cognitive control participants are instructed to perform a given action to obtain a specific outcome. Accordingly, research on the impact of reward signals on adaptive control is thus mainly limited to instructed task goals and does not consider how reward signals interact with outcome representations in controlling behavior (Dickinson & Balleine, 1994). We propose that analyzing the interplay between outcome representations and positive reward signals offers a more comprehensive examination of adaptive control of human action. In the next section, we discuss some recent research that examines this interplay in more detail.

The combined role of outcome representations and reward signals

The combined role of outcome representations and reward signals has been examined to explore the building blocks of adaptive control in goal pursuit (Custers & Aarts, 2005; 2010). For instance, the activation of the outcome representation of physical exertion facilitated effortful control in action when this outcome representation was immediately followed by reward signals (i.e., positive words) in an evaluative conditioning procedure (Aarts, Custers, & Marien, 2008). Participants resisted the pressure to release but persisted in squeezing a handgrip. Furthermore, this study provided evidence for the distinct roles of outcome representations and reward signals. The mere activation of the outcome representation facilitates initiation of the action, but did not increase control unless positive reward signals were attached to it. Several other studies have also demonstrated the function of reward signals in mobilizing action control (e.g., Capa, Cleeremans, Bustin, & Hansenne, 2011; Köpetz, Faber, Fishbach, & Kruglanski, 2011;Veltkamp, Aarts, & Custers, 2011).

Building on this line of research, we investigated whether the pairing of positive reward signals with outcome representations translates into adaptive control in terms of making people more flexible in goal-directed behavior (Marien, Aarts, & Custers, 2012). In a modification of a set-switch paradigm (Dreisbach & Goschke, 2004), participants had to turn on a light by pressing either a left or a right key. On each trial, the correct response was indicated by a dot of a particular color appearing either left or right. A dot of a different color was presented in the opposite location, but had to be ignored. Before each trial, a cue appeared consistently reminding people of the outcome (turn on light). These cues were immediately followed by positive or neutral stimuli. After some trials, participants had to ignore the color they had to attend to earlier and react to a new color. Participants in the positive reward signal condition had significantly lower switch costs than those in the neutral condition. These findings suggest that being able to swiftly switch the course of action to obtain an outcome is dependent on whether the outcome representation of the action was co-activated with reward signals.

Whereas most studies on the combined role of outcome representations and reward signals in facilitating control consider the outcomes as given, from research on ideomotor theory one would expect that these outcome representations are normally acquired in daily life as a result of learning that the outcome follows from an action (Elsner & Hommel, 2001). Thus, according to our present analysis positive reward signals should only increase control when an action is represented in terms of its outcome. Specifically, only when the presentation of a specific stimulus follows an action rather than preceding it, will an accompanying positive reward signal cause people to engage in controlled behavior to obtain the outcome.

In a recent test of this idea (Marien, Aarts, & Custers, in preparation-b), participants had to execute an action (pressing a key) that was either preceded or followed by a stimulus on the computer-screen (e.g., the word “scissors”). The stimulus was accompanied by a neutral or positive reward signal by presenting a spoken word through headphones (e.g., the word “with” or “nice”). Thus, the stimulus represented an outcome of an action or not, and this outcome representation was co-activated with a reward signal or not. After some pairings, participants were presented with the stimulus on the screen and had to press another key repeatedly to move the stimulus closer to themselves in an easy way (one single key) or a more demanding way (multiple keys). Faster repetitive action in this task implies more control. Results showed that participants were faster in moving the stimulus to themselves only when it represented an outcome of their action and was co-activated with a positive reward signal. This effect was more pronounced when moving the stimulus to themselves was demanding. These findings suggest that adaptive control of goal-directed behavior is more likely to occur when positive reward signals accompany the process of representing action in terms of outcomes. Moreover, resources to control behavior seem to be allocated to obtain the outcome according to a principle of conservation (Silvestrini & Gendolla, 2013).

Conclusion, implications and prospects

We proposed that an integration of ideomotor accounts with affective-motivational accounts of action can shed new light on the control mechanisms underlying human goal-directed behavior. Although ideomotor theorizing offers a framework to understand how action-effect knowledge is acquired and how outcome representations select action, it is less explicit in predicting when and how control of behavior results from the activation of outcome representations. To understand the emergence of adaptive control reward signals should be taken into account. Although there is some research investigating the impact of reward signals on action-effect learning, the analysis is mainly focused on how it affects the binding strength and performance of the associated action (Muhle-Karbe & Krebs, 2012).

We also suggest that motivational accounts of adaptive control should incorporate more insights of ideomotor theory. Adaptive control processes are closely linked with reward processing, but the role of outcome representations is under-investigated in this literature. It is important for reward signals to connect with outcome representations in order for them to have a profound effect on adaptive control. The present analysis suggests that positive signals of different sources denote the value of an outcome and facilitate control of behavior. This implies that the influence of reward signals on recruiting executive control resources might not follow a direct path, but is mediated by the assigned value of the outcome representation. Future research could address (1) how personal value of an outcome representation results from reward signals, and (2) whether personal value mediates the instigation of control.

One way to approach this matter is by analyzing the neurocircuits prioritizing and controlling goals. Specifically, recent work in cognitive neuroscience proposes the involvement of specific neurotransmitter systems that cause people to exploit (being rigid to reach a goal) or to explore (prioritizing other goals) their environment (Aston-Jones & Cohen, 2005). Noradrenergic pathways in the brain are suggested to be associated with exploitation while dopaminergic pathways are supposed to be engaged in exploration.

This neurocircuit analysis of adaptive control can benefit from the present analysis. Adaptive control in terms of flexible or rigid/persistent processes may be dependent on the level of behavioral representation to which reward signals are attached. Goal-directed behavior is hierarchically structured (Botvinick, 2008), and hence the control of behavior may be directed at the level of action (means) representations or outcome (goal) representations depending on context and individual differences (Vallacher & Wegner, 1989). For example, goal-directed control of turning on a light may be identified and guided by the representation of "pressing the button" or "turning on the light". So when representations of means are paired with reward signals action control is more likely to occur on the means level. Paradoxically, this could lead to more rigidity in control. We found that participants were less prone to switch to another action when the representation of the means was cued and paired with reward signals (Marien, et al., 2012). In other words, when an outcome representation can be regarded as a subgoal of another outcome representation higher in the hierarchy (i.e., "pressing the key" in order to "turn on the light"), treating it with reward signals will increase local exploitive focus instead of broad explorative processing (Gable & Harmon-Jones, 2008). Taking the level of behavior representation into account may lead to specific predictions when reward signals produce a flexible or rigid mode of control.

Research on adaptive control of human action can advance by looking at outcome representations in combination with reward signals. It can especially help us to understand how the human mind functions optimally in the ever changing environment that we inhabit

Chapter 3

Reward-driven modulation of adaptive control: How prospective monetary gains interact with unpredictable control demands

Abstract

Shifting attention is an effortful control process and incurs a cost on the cognitive system. Previous research suggests that rewards, such as monetary gains, will selectively enhance the ability to shift attention when this demand for control is explicitly cued. Here, we hypothesized that prospective monetary gains will selectively enhance the ability to shift attention even when control demand is unpredictable and not cued beforehand in a modality shift paradigm. In two experiments we found that target detection was indeed facilitated by reward signals when an unpredictable shift of attention was required. In these crossmodal trials the target stimulus was preceded by an unpredictive stimulus directing attention to the opposite modality (i.e., visual-auditory or auditory-visual). Importantly, there was no reward effect in ipsimodal trials (i.e., visual-visual or auditory-auditory). Furthermore, the absence of the latter effect could not be explained in terms of physical limits in speed of responding. Potential motivation of monetary rewards thus selectively translates into motivational intensity when control (i.e., switching) is demanded in unpredictable ways.

This chapter is based on: Marien, H., Aarts, H., & Custers, R. (2014). *Reward-driven modulation of adaptive control: How prospective monetary gains interact with unpredictable control demands.* Manuscript revised and resubmitted for publication.

The dynamic world that people live in requires them to maintain and adapt their behavior accordingly to cope with situational changes. To face these challenges humans are equipped with a cognitive system that helps them to keep a behavioral goal active in mind while inhibiting distracting stimuli and also enabling them to shift to alternative actions quickly when unusual events arise and interfere with the current course of action (Miyake & Shah, 1999). This human adaptive control system is far from efficient though. The underlying processes are effortful and its resources are only available to a limited extent (Kahneman, 1973; Navon, 1984; Pashler, 1998). To avoid wasting energy it is thus key to conserve these resources optimally and only apply them to the degree that they are useful.

According to motivation intensity theory the need for effort is determined by the difficulty of activity that must be carried out to attain desired outcomes, such as monetary rewards (Brehm & Self, 1989; Gendolla, Wright, & Richter, 2011). Thus as long as effort allocation is worthwhile it will correspond with the assessed difficulty and control demands of the task. In most research on motivation intensity theory the task demands are clearly presented to participants so that they can anticipate whether to exert effort based on their potential motivation. Potential motivation is defined as the upper limit of the amount of effort a person is willing to exert (Wright, 2008). Thus a person will expend the maximum amount of effort that is justified by the related benefit when demands are predicted to be high. However, it is not always possible to know and predict in advance how demanding it will be to maintain and adapt behavior successfully. This raises the question of how rewards modulate effortful adaptive control when demands are not known well in advance.

In many everyday situations the required demands of a task vary over time, and even though benefits might be high people will not overinvest their resources and waste energy on a regular basis. For example, the amount of effort needed to win a sports event (e.g., a cycling race or a tennis match) is strongly variable and unpredictable over time, but athletes do not usually invest maximum effort all the time according to the value of the reward (e.g., price money). Rather, the amount of effort invested will more likely correspond with the required effort to finish the task. In the present article we explore this notion in more depth and propose that potential motivation will only translate in effort mobilization when adaptive control is actually needed, thus also when demand for control cannot be predicted in advance.

This notion is based on the fact that motivational processes are closely linked with adaptive control of human action (Chiew & Braver, 2011; Marien, Aarts, & Custers, 2013). Recruiting adaptive control incurs a cost on the system that needs to be compensated by a significant benefit in the end (Navon & Gopher, 1979). When the anticipated outcome does not carry sufficient reward value spending mental effort to attain it would be a waste of energy. Therefore people have acquired the ability to readily detect reward value in order to assess whether an anticipated outcome is desirable and worth the effort (Dolan, 2002). In fact, reward signals are integrated with executive functions in such a way that they facilitate the allocation of these limited resources when behavioral demands need to be met (Pessoa, 2009). Thus when rewards are at stake they mainly serve the function to mobilize effort when adaptive control is demanded by the situation, and their effect should be minimal when control is not demanded. In line with the principle of resource conservation reward signals increase potential motivation which will only translate in motivational intensity in terms of adaptive control processing when this is effectively required.

Research examining the role of motivation in control processes often confirms the basic idea that higher rewards, including monetary ones, lead to higher allocation of adaptive control resources (e.g., Pessoa & Engelmann, 2010; Watanabe, 2007). However, the distinction between potential motivation and motivational intensity is usually not made, so that most reported reward effects seem to follow the simple one-to-one relation: the higher the value of a reward the more resources are allocated to attain it (Engelmann, Damaraju, Padmala, & Pessoa, 2009; Pessiglione et al., 2007). The available evidence at first sight seems to contradict the principle of resource conservation. The reason for this is that the requirement for adaptive control is usually not manipulated in this research, which causes the reward information to become confounded with effort requirement. In this case, a reward signal operates merely as a performance standard that enhances effort on a task, especially in paradigms using performance contingent rewards (e.g., Bijleveld, Custers, & Aarts, 2010). To actually test the principle of resource conservation, then, rewards and control demands need to be manipulated independently from each other.

There is some recent work that addresses this dissociation more explicitly. In one study, it was found that participants recruit more resources when high rewards are at stake, but only when the task required considerable mental effort (Bijleveld, Custers, & Aarts, 2009). On trials where participants had to recall 5 digits rewards boosted mental effort as revealed by pupil dilation, but there was no reward effect when participants had to recall 3 digits. However, in this task participants were explicitly cued beforehand about the number of digits to recall, which gave them the opportunity to refrain from resource investment in a strategic way. Similar findings have also been reported with other tasks that vary in demand (e.g., Eubanks, Wright, & Williams, 2002). In another line of research the demand for control was manipulated in the sense that some trials required switching and others did not, indicated by a specific cue (Shen & Chun, 2011). Indeed it was found that increases in reward had an especially pronounced effect on switch trials, so that switch costs were reduced. However, here the requirement to switch was also explicitly cued beforehand, which again made the cost of switching predictable and anticipatable. Thus, although the interaction between effort requirements and rewards gain more and more attention in the recent literature (e.g., Bijleveld, Custers, & Aarts, 2012; Treadway, et al., 2011), it remains to be elucidated whether reward signals follow the principle of resource conservation when control demands are unpredictable.

In the present article we examine this idea by using a modality shift paradigm. This paradigm allows us to implicitly vary control demands, which makes the requirement for switching unpredictable. Participants are instructed to respond to visual or auditory target stimuli as fast as possible. Immediately before presentation of these targets (i.e., S2) a preparatory stimulus (S1) is either presented in the same modality as the target (ipsimodal trials, e.g., visual-visual), or in the opposite modality of the target (crossmodal trials, e.g., visual-auditory). The latter type of trials requires control processing, because participants have to switch their prepared modality (e.g., visual) to the different modality (e.g., auditory). This typically results in a delayed response time caused by a modality switch cost, especially when the time between S1 and S2 is short (i.e., between 150 and 600 ms) (Rodway, 2005; Turatto, Benso, Galfano, & Umiltá, 2002). It is important to note that the modality of S1 is not predictive of the modality of S2, which makes each trial completely ambiguous in terms of control demands. Furthermore, when modalities do not have to be switched (i.e., during ipsimodal trials) control demands are reduced to a minimum. The fact that this is a simple reaction time task contributes to this feature, because there is no need to select a response based on stimulus-response rules that need to be kept in working memory. The delayed response will thus more purely reflect the control component of switching attention and a modulation of this switch cost will correspond with the amount of allocated resources.

To test the effects of rewards on resource allocation of adaptive control, on half of the trials participants were presented with a 5 eurocents coin which they could earn; on other trials this reward signal of the coin was absent. It is expected that participants will respond significantly faster to crossmodal trials when a reward is at stake. Furthermore, even though control demands are unpredictable, we do not expect a reward effect of speeded responding on ipsimodal trials, because we suggest that effort mobilization can only occur when adaptive control is actually required. Two experiments are presented to test these ideas.

Experiment 3.1

To investigate the role of reward signals in modulating the allocation of adaptive control resources we used a simple RT modality shift paradigm and tested reward effects in both crossmodal trials (i.e., S1-S2 = visual-auditory or auditory-visual) and ipsimodal trials (i.e., visual-visual or auditory-auditory). The stimulus onset asynchrony (SOA) between S1 and S2 was fixed at 250 ms. To prevent participants from anticipating their responses, catch trials in which S2 was not presented were also included. In half of the trials participants could earn a monetary reward of 5 eurocents when they responded to S2 within 500 ms or when they successfully refrained from responding to catch trials.

Method

Participants and design. Twenty-six participants (11 males; mean age 21.9) took part in the experiment. All had normal hearing and normal or corrected-to-normal vision. Participants were paid €2 for cooperation and could earn extra money during the experiment. The simple RT task used a 2 (Reward: 0 cent vs. 5 cents) x 2 (Trial type: ipsimodal vs. crossmodal) within participants design.

Procedure and materials. Participants were tested individually in a cubicle and the experiment was presented on a 60-Hz computer screen. They were instructed to perform a stimulus detection task in which they had to respond to visual or auditory stimuli as fast as possible. They learned that before the onset of the target stimulus (S2) a warning stimulus (S1) would be presented. The modalities of the stimuli (S1 and S2) were determined at random. Participants were also informed that on some trials they could earn 5 eurocents for good performance.

Visual stimuli were presented in the center of the screen on a black background and consisted of a square (0.95° of visual angle) that was colored red for S1 and yellow for S2. Auditory stimuli were presented at 80 dB(A) through headphones and consisted of a 900Hz pure tone for S1 and a 1800Hz pure tone for S2. The beginning of an unrewarded trial was signaled by the simultaneous onset of a brown circle (3.10° of visual angle) along with a 900 + 1800Hz tone at 80 dB(A) for 300 ms. On rewarded trials instead of the brown circle a five eurocents coin (3.10° of visual angle) was presented for 300 ms. After a further 1700 ms the preparatory stimulus S1 (either visual or auditory) was presented for 100 ms. Then, after another 150 ms the target stimulus S2 (visual or auditory) was presented for 100 ms. Participants were required to press the middle button of a response box as soon as S2 was detected. Allowed time for responding was 1000 ms, but on rewarded trials they could only earn five eurocents if they responded within 500 ms. On catch trials, in which S1 was not followed by S2, participants had to refrain from responding to perform accurately and earn the reward.

Participants first performed a number of practice trials until they learned to respond within 500 ms. A block of (unrewarded) practice trials consisted of eight S1-S2 trials (2 visual-visual, 2 visual-auditory, 2 auditory-auditory, 2 auditory-visual) and 4 catch trials (2 visual, 2 auditory). Participants were instructed to respond within 500 ms on the regular trials and not to respond on catch trials. If participants met these criteria and scored at least 11 out of 12 trials they advanced to the experimental trials. If they scored less than 11 out of 12 they were redirected to the block of 12 practice trials. On average participants performed three practice blocks before they advanced to the experimental trials.

Participants completed 100 experimental trials (40 ipsimodal trials (i.e., 20 visual-visual and 20 auditory-auditory); 40 crossmodal trials (i.e., 20 visual-auditory and 20 auditory-visual); and 20 catch trials) presented in random order. There was a short break of 30 seconds after 50 trials. Half of the trials were reward trials, thus participants could earn a an extra €2,50 in total if they met the performance criteria on all rewarded trials. At the end of the experiment participants were informed about their performance and how much extra money that they had earned. Then they immediately received the monetary reward plus the regular compensation from the experimenter.

Results

In the following analyses we excluded RTs that were shorter than 100 ms or longer than 2.5 standard deviations from the mean per condition (cf. Rodway, 2005). This resulted in the removal of 3.1% of the data. The remaining RT data were subjected to a 2 (Reward: 0 cent vs. 5 cents) x 2 (Trial type: ipsimodal vs. crossmodal) repeated measures ANOVA.[1]

Analyses revealed a main effect of reward, $F(1, 25) = 12.57$, $p = .002$, $\eta^2 = .34$, with participants responding more rapidly to rewarded trials (M = 306 ms, SD = 43) than to unrewarded trials (M = 316 ms, SD = 44). The main effect of Trial type was also significant, $F(1, 25) = 125.24$, $p < .001$, $\eta^2 = .84$, with participants responding faster in ipsimodal trials (281 ms, SD = 42)

[1] It should be noted that the main pattern of results was similar for both types of modalities (i.e., visual vs. auditory) and will not be discussed in further detail.

than in crossmodal trials (340 ms, *SD* = 47), replicating the standard modality shift effect. More importantly, the expected Reward x Trial type interaction was significant, $F(1, 25) = 6.15$, $p = .020$, $\eta^2 = .20$, showing that the effect of Reward was only significant in the crossmodal condition. More specifically, Figure 3.1 shows that participants responded faster to rewarded crossmodal trials than to unrewarded crossmodal trials, $F(1, 25) = 14.28$, $p = .001$, $\eta^2 = .36$, but there was no difference in RT between rewarded and unrewarded trials in the ipsimodal condition, $F(1, 25) = .55$, $p = .466$.

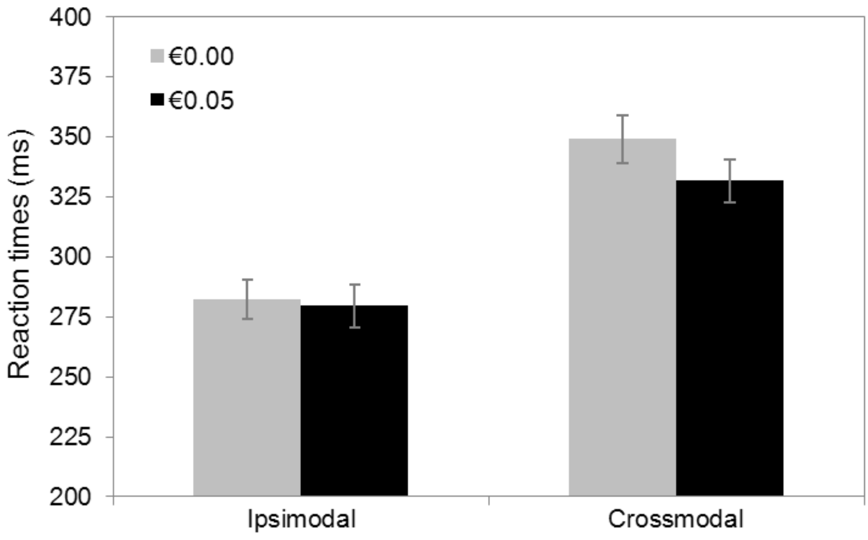

Figure 3.1. Mean reaction times in milliseconds for Ipsimodal and Crossmodal trials in Experiment 3.1 as a function of Reward, with error bars representing one standard error of the mean.

Participants responded within 500 ms (i.e., the response criterion for the reward) in 97.6% (*SD =* 4.5) of the trials. These data were subjected to a 2 (Reward: 0 cent vs. 5 cents) x 2 (Trial type: ipsimodal vs. crossmodal) repeated measures ANOVA. The main effect of Reward was not significant, $F(1, 25) = 1.54$, $p = .227$. However, there was a main effect of Trial type, $F(1, 25) = 22.91$, $p < .001$, $\eta^2 = .48$, with participants reaching the response criterion more often in ipsimodal trials ($M = 99.5\%$, $SD = 1.3$) than in crossmodal trials ($M = 95.6\%$, $SD = 4.6$). The interaction of Reward x Trial type was also significant, $F(1, 25) = 6.31$, $p = .019$, $\eta^2 = .20$. More specifically, participants reached the response criterion more often in rewarded crossmodal trials ($M = 96.8\%$, $SD = 4.3$) than in unrewarded crossmodal trials ($M = 94.4\%$, $SD = 6.3$), $F(1, 25) = 4.47$, $p = .045$, $\eta^2 = .15$, but there was no difference between rewarded and unrewarded trials in the ipsimodal condition, $F(1, 25) = 3.93$, $p = .059$.

Participants were highly accurate in not responding to catch trials ($M = 91.9\%$, $SD = 7.1$). The accuracy data of catch trials were subjected to a 2 (Reward: 0 cent vs. 5 cents) x 2 (S1 modality: visual vs. auditory) repeated measures ANOVA. The main effect of Reward did not reach significance, $F(1, 25) = 2.41$, $p = .133$, nor were the main effect of S1 modality, $F(1, 25) = .68$, $p = .416$, and the interaction effect significant, $F(1, 25) = .33$, $p = .574$.

Discussion

The results of Experiment 3.1 are in line with our expectations that participants responded significantly faster and reached the response criterion more often when a reward was at stake during crossmodal trials, but there was no speeded responding during rewarded ipsimodal trials. Reward signals thus specifically reduced switch costs and did not affect perceptual performance when no control was demanded. Moreover, these findings extend previous research because control demands were unpredictable. This indicates that reward signals operated according to the principle of resource conservation so that effort was only mobilized at the moment that adaptive control processing was actually demanded.

Experiment 3.2

Although the results of Experiment 3.1 clearly show that reward effects were specific to crossmodal trials, the absence of the reward effect in ipsimodal trials is still open to one important alternative explanation. The fact that participants did not decrease their speed of responding to rewarded ipsimodal trials does not necessarily mean that they did not allocate effort to do so. It is also possible that they did allocate effort, but that it simply did not show up in the RT data because participants could not respond any faster due to motoric limitations, so that the null effect was a result of a floor effect. To rule out this alternative explanation the second experiment was an exact replication of the first experiment with one exception, namely the response criterion was lowered from 500 to 400 ms. This allowed us to replicate the results of Experiment 3.1 with a more strict response criterion. Moreover, we could also examine whether it is possible to respond faster in this simple RT task. It is expected that participants are able to respond faster in this task, but that reward signals still do not have an impact on speed of responding when adaptive control processing is not demanded.

Method

Participants and design. Thirty-five participants (16 males; mean age 21.1) took part in the experiment. All had normal hearing and normal or corrected-to-normal vision. Participants were payed €2 for cooperation and could earn extra money during the experiment. The simple RT task used a 2 (Reward: 0 cent vs. 5 cents) x 2 (Trial type: ipsimodal vs. crossmodal) within participants design.

Procedure and materials. Procedure and materials were exactly the same as in Experiment 3.1 with one exception. On rewarded trials participants could only earn five eurocents if they responded within 400 ms instead of 500 ms. Thus in the practice trials participants were instructed to respond within 400 ms on the regular trials and not to respond on catch trials. Again, if participants met these criteria and scored at least 11 out of 12 trials they advanced to the experimental trials. If they scored less than 11 out of 12 they were redirected to the block of 12 practice trials. On average participants performed four practice blocks before they advanced to the experimental trials that were the same as in Experiment 3.1.

Results and discussion

In the following analyses we excluded RTs that were shorter than 100 ms or longer than 2.5 standard deviations from the mean from the mean per condition (cf. Rodway, 2005). This resulted in the removal of 5.0% of the data. The remaining RT data were subjected to a 2 (Reward: 0 cent vs. 5 cents) x 2 (Trial type: ipsimodal vs. crossmodal) repeated measures ANOVA.

Analyses revealed a main effect of reward, $F(1, 34) = 5.38$, $p = .027$, $\eta^2 = .14$, with participants responding more rapidly to rewarded trials (M = 283 ms, SD = 36) than to unrewarded trials (M = 289 ms, SD = 36). The main effect of Trial type was also significant, $F(1, 34) = 157.81$, $p < .001$, $\eta^2 = .82$, with participants responding faster in ipsimodal trials (259 ms, *SD* = 31) than in crossmodal trials (313 ms, *SD* = 42), replicating the standard modality shift effect. More importantly, the expected Reward x Trial type interaction was significant, $F(1, 34) = 5.37$, $p = .027$, $\eta^2 = .14$, showing that the effect of Reward was only significant in the crossmodal condition. More specifically, Figure 3.2 shows that participants responded faster to rewarded crossmodal trials than to unrewarded crossmodal trials, $F(1, 34) = 8.43$, $p = .006$, $\eta^2 = .20$, but there was no difference in RT between rewarded and unrewarded trials in the ipsimodal condition, $F(1, 34) = 1.06$, $p = .311$.

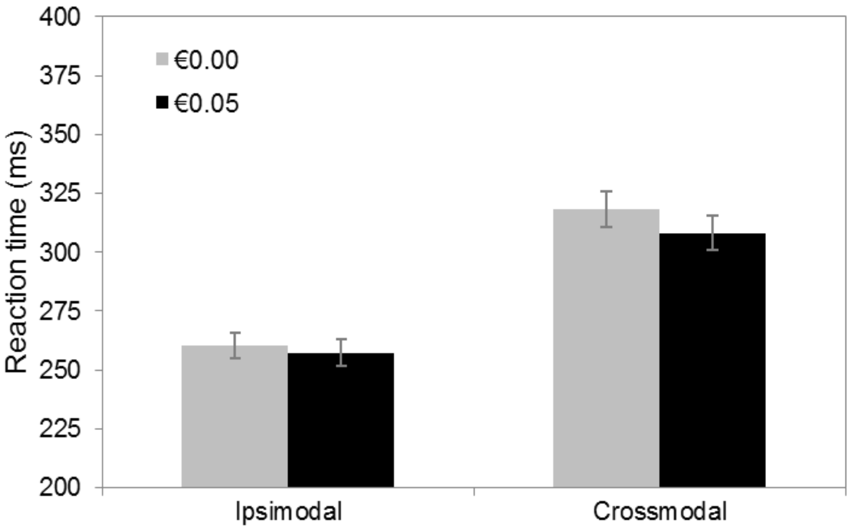

Figure 3.2. Mean reaction times in milliseconds for ipsimodal and crossmodal trials in Experiment 3.2 as a function of Reward, with error bars representing one standard error of the mean.

Participants responded within 400 ms (i.e., the response criterion for the reward) in 93.1% (*SD* = 9.6) of the trials. These data were subjected to a 2 (Reward: 0 cent vs. 5 cents) x 2 (Trial type: ipsimodal vs. crossmodal) repeated measures ANOVA. The main effect of Reward was not significant, $F(1, 34) = .47$, $p = .496$. However, there was a significant main effect of Trial type, $F(1, 34) = 33.58$, $p < .001$, $\eta^2 = .50$, with participants reaching the response criterion more often in ipsimodal trials (*M* = 98.0%, *SD* = 1.8) than in crossmodal trials (*M* = 88.2%, *SD* = 9.9). The interaction of Reward x Trial type was not significant, $F(1, 34) = 1.32$, $p = .259$, $\eta^2 = .20$.

Participants were fairly accurate in not responding to catch trials (*M* = 89.3%, *SD* = 10.4%). The accuracy data of catch trials were subjected to a 2 (Reward: 0 cent vs. 5 cents) x 2 (S1 modality: visual vs. auditory) general linear model repeated measures analysis. The main effect of reward, $F(1, 34) = .30$, $p = .586$, the main effect of S1 modality, $F(1, 34) = 1.25$, $p = .270$, and the interaction effect were not significant, $F(1, 34) = .13$, $p = .723$.

Cross-study analyses. To examine the influence of the response criterion we compared the two experiments and subjected the RT data to a 2 (Response criterion: 500 ms vs. 400 ms) x 2 (Reward: 0 cent vs. 5 cents) x 2 (Trial type: ipsimodal vs. crossmodal) mixed factorial repeated measures ANOVA with the first factor as a between subjects factor. The main effect of response criterion was significant, $F(1, 59) = 5.99$, $p = .017$, $\eta^2 = .09$, with participants in the second experiment (with a response criterion of 400 ms) responding more rapidly (*M* = 286 ms, *SD* = 50) than participants in the first experiment with a 500 ms response criterion (*M* = 310 ms, *SD* = 59). Furthermore, the two-way interaction of Reward x Trial type, $F(1, 59) = 10.30$, $p = .002$, $\eta^2 = .15$, was significant showing that participants responded faster to rewarded crossmodal trials than to unrewarded crossmodal trials, $F(1, 59) = 21.86$, $p < .001$, $\eta^2 = .27$, but there was no difference in RT between rewarded and unrewarded trials in the ipsimodal condition, $F(1, 59) = 2.10$, $p = .153$. Moreover, the three-way interaction of Response criterion x Reward x Trial type was not significant, $F(1, 59) = .61$, $p = .437$). The main results are summarized in Figure 3 where the three-way interaction is represented in terms of difference scores between rewarded and unrewarded trials. Whereas these summary findings across the two studies should be interpreted with caution, they suggest that the reward effect is independent of response criterion and is only significant in the crossmodal condition.

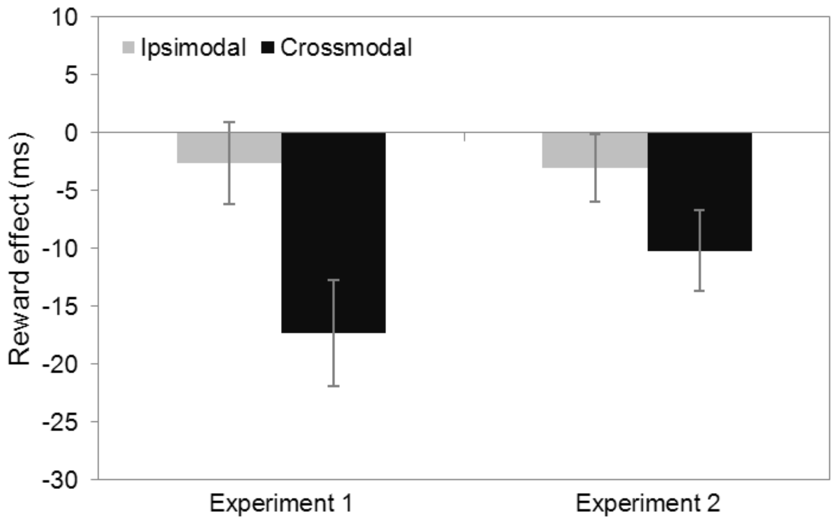

Figure 3. Reward effects as mean difference scores (RT rewarded trials – RT unrewarded trials) in milliseconds for Experiment 3.1 and Experiment 3.2 as a function of Trial type (Ipsimodal vs. Crossmodal), with error bars representing one standard error of the mean.

The findings of Experiment 3.2 replicate and extend the findings of Experiment 3.1 by demonstrating that the reward effect was specific to trials requiring adaptive control processing (i.e., switching), and again there was no reward effect in trials where no control was demanded. The absence of the latter effect is hard to explain in terms of physical limits in speed of responding, because participants in Experiment 3.2 (response criterion 400 ms) were able to respond significantly faster than participants in Experiment 3.1 (response criterion 500 ms). Although this difference might be due to any other factor that systematically differed between the two studies, it can also suggest that resources could have been allocated to decrease RT to ipsimodal trials in Experiment 3.1 as well, but that this did not happen because adaptive control processing, in terms of switching, was not demanded.

General discussion

The purpose of the current research was to investigate the modulatory role of reward signals in adaptive control processing when demand is unpredictable. Across two experiments that used a modality shift paradigm we found that prospective monetary gains only facilitated responses to crossmodal trials and did not have an effect on ipsimodal trials. These findings are in line with motivation intensity theory in the sense that they follow the principle of resource conservation (Brehm & Self, 1989). Reward signals increase potential motivation which only translates into motivational intensity in terms of adaptive control processing when this is effectively required. Furthermore, these findings also indicate that reward signals do not simply boost mental effort when control demands are unpredictable. Their role is more sophisticated even in these unpredictable situations. Reward-driven modulation of adaptive control processing is thus managed in an optimal way so that unnecessary waste of resources is kept to a minimum.

This line of reasoning fits nicely with the circumstances of everyday life where effort requirements are highly dynamic and unpredictable. However, this aspect is often not reflected in experimental designs. Effort requirements are often explicitly cued beforehand, thereby opening the possibility for participants to weigh the value of rewards against the required effort and make a deliberate decision about effort investment (Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009). Here, we used the modality shift paradigm in which such cueing is absent, and hence participants do not make such deliberate decisions. Accordingly, the present findings suggest that this decision making process is not necessary to conserve resources in a strategic way. This concurs with previous research that has found evidence for the idea that reward responses are adjusted to current demand information rather than being a predefined consequence of anticipated effort requirements (Bijleveld et al., 2012). This efficient online integration of reward signals and control demands finds its roots in the close relationship between motivational processes and the adaptive control system in the human brain (Kouneiher, Charron & Koechlin, 2009). Through these connections reward signals serve the function to allocate adaptive control resources when this is demanded by the situation.

The brain can rapidly detect demands for control through a system of conflict monitoring which is represented by activity in the anterior cingulate cortex (ACC) (Botvinick, Braver, Barch, Carter, & Cohen, 2001).

Whenever a mentally challenging situation is encountered an error-related signal is produced by the ACC which is send to adaptive control networks to call for their involvement (Carter et al., 1998). This signal in the ACC is also correlated with cardiovascular reactivity, which is a clear correlate of effort mobilization (Critchley, Corfield, Chandler, Mathias, & Dolan, 2000; Gendolla et al., 2011). The capacity to readily detect control demands thus ensures an immediate mobilization of adaptive control resources without the need for anticipatory effort investments that need to be sustained over prolonged periods of time.

This just-in-time mobilization of resources may be a form of reactive control processing, which stands in contrast with proactive control processing (Braver, 2012). Whereas proactive control is reflected by the active maintenance of task goals, reactive control is reflected by the bottom-up reactivation of task goals. Thus whenever a reward is at stake this information can either be kept activated during the entire task or it can be used only as needed. The findings of the present study suggest that prospective monetary gains followed the second route of reactive control to produce their effects on adaptive control. Although it remains a speculation, recent research does suggest that the route of transient activation can be as successful as the route of sustained activation in prospective memory retrieval (McDaniel, LaMontagne, Beck, Scullin, & Braver, 2013). Keeping reward information activated in mind is thus not necessary for it to have an impact at exactly the right time, namely at the unpredictable moment of control demand. The principle of resource conservation thus seems to be reasonably supported by the neural architecture of reward signals and adaptive control.

To conclude, reward signals play a very important role in the adaptive control of human action. Through their efficient interaction with control demands they manage to conserve resources even when demands are unpredictable. Future research can benefit from an integrative perspective of reward signals and control demands to further our understanding of how people deal with the challenges of their environment in an economical way.

Chapter 4

Being flexible or rigid in goal-directed behavior: When positive affect implicitly motivates the pursuit of goals or means

Abstract

Building on previous research on the role of positive affect as implicit motivator we investigated both flexibility and rigidity in goal-directed behavior. Given that goal-directed behavior can be represented in terms of goals or means, we suggest that goal-directed behavior is more flexible in switching means when positive affect implicitly motivates a person to reach the goal, but is more rigid in switching means when positive affect implicitly motivates a person to perform a specific means. Three experiments corroborated this idea: the speed of switching from a learned goal-directed means to a new means was facilitated when positive affect was attached to the representation of the goal, whereas this switching was slowed down when positive affect was attached to the representation of the learned means. Together, these findings provide new insights into the occurrence of flexibility and rigidity in implicitly motivated goal-directed behavior.
Keywords: flexibility; rigidity; positive affect; implicit motivation; unconscious goal pursuit.

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A substantial part of human behavior is goal-directed. People are motivated to maintain and adapt their course of action in a dynamic world to reach behavioral outcomes, and thus engage in goal-directed behavior in a rigid and flexible way. For instance, the goal to visit the office can be attained in a rigid way by always taking the car or in a flexible way by switching between different transport modes. The present research addresses the question when goal-directed behavior may be more flexible or rigid in switching between means to attain goals.

Both rigid and flexible goal-directed behavior can be the result of people's motivation to engage in goal-directed behavior (Aarts, 2012). Increased motivation to engage in goal-directed behavior causes people to maintain or adapt their actions, depending on the situation at hand (e.g., when the dominant instrumental action calls for additional effort or other actions are required to reach the goal). While the motivation and control of goal-directed behavior is traditionally thought to be associated with conscious thought and intent, recent research shows that goal-directed behavior also arises from unconscious processes (Bargh, Gollwitzer, & Oettingen, 2010). Specifically, several studies have demonstrated that people are implicitly motivated to control their goal-directed behavior when the cognitive representation of a behavior or outcome is attached to a positive affective tag (Aarts, Custers, & Marien, 2008; 2009; Aarts, Custers, & Veltkamp, 2008; Capa, Cleeremans, Bustin, Bouquet, & Hansenne, 2011; Custers & Aarts, 2005; 2007; Ferguson, 2007; Holland, Wennekers, Bijlstra, Jongenelen, & Van Knippenberg, 2009; Van den Bos & Stapel, 2009; Veltkamp, Aarts, & Custers, 2008; 2011).

Importantly, goal-directed behavior is hierarchically structured and consists of a cognitive representation of the goal or outcome and of the means (e.g., Aarts & Dijksterhuis, 2000; Kruglanski et al., 2002; Vallacher & Wegner, 1987). Therefore, the representation of goals and means can be primed (e.g., by cues in the environment), and a person can represent and control her behavior in terms of the goal or the means serving the goal. Interestingly, the notion that positive affect can implicitly motivate people to control goal-directed behavior opens the possibility that flexibility or rigidity depends on whether positive affect is attached to the goal representation or the means representation. Here we examine this issue by suggesting that the way people represent their behavior determines whether implicit motivation materializes in either flexible or rigid goal-directed behavior. Specifically, we propose that when the cognitive representation of the goal or outcome is attached to positive affect, goal-directed behavior may become more flexible in that it switches between means. However, when the cognitive representation of the means is attached to positive affect goal-directed behavior may become more rigid.

One way to understand how positive affect attached to a goal or means representation can foster a more flexible or rigid mode of switching between means is to consider how positive affect motivates people to control their behavior. First, the level at which people represent their behavior determines the reference point at which perception and lower actions are directed (Prinz, 1997; Powers, 1973). For instance, a person who represents the act of commuting as going to the office (goal level) controls her behavior in terms of going to the office. However, if the same act is represented as taking the car (means level) then behavior is more likely to be controlled in terms of taking the car. Thus, in both cases people control perception and action in accordance with the accessible (goal or means) representation, only on different levels of information processing.

Whereas the occurrence of different levels of action control is well-studied in research on executive control (Botvinick, 2008; Monsell & Driver, 2000), less is known how control processes render goal-directed behavior flexible or rigid as a function of the motivational significance to execute control. Because research indicates that positive affect attached to the representation of behavior acts as a reward signal that motivates the control of behavior at the level at which the behavior is represented (for a mechanistic account of this process, see Custers & Aarts, 2010), differences in representation levels may have corollaries for how the positive reward signal motivates a flexible or more rigid course of action when a switch to another means is required. Specifically, both flexibility and rigidity are the result of an increased motivation to execute control processes, but they are correlated with different key components within the executive function, namely switching and focussing of attention and action (Dijksterhuis & Aarts, 2010; Smith & Jonides, 1999).

The line of reasoning addressed above suggests that positive affect can implicitly motivate people to control their goal-directed behavior in a more flexible or rigid way. If people represent their behavior in terms of the goal guiding their actions, then positive affect motivates people to control their behavior at the goal level. This enhanced goal motivation should render goal-directed behavior more flexible, as people are keen to switch attention to other means in order to reach the goal if the previous means is no longer valid. However, if people represent behavior in terms of means leading to the goal, then positive affect motivates people to control their behavior at the means level. Enhanced motivation to perform the means renders goal-directed behavior more rigid, as people are keen to focus attention on the means to reach their goal, even though the old means is invalid and a switch to new means is required to reach the goal. Accordingly, flexibility and rigidity in goal-directed behavior can be seen as resulting from the implicit motivation to control behavior at different levels.

Three experiments tested these novel and intriguing ideas. Specifically, we examined the costs associated with switching from one means to another means as part of executing goal-directed behavior. In the first and third experiment we used a modified version of a set-shifting task (Chiu, Yeh, Huang, Wu & Chiu, 2009; Dreisbach & Goschke, 2004), in which increases and decreases in switch costs concurred with rigid versus flexible control of behavior, respectively (Meiran, 2010). In this task, participants' goal is to categorize letters presented on the computer-screen by means of responding to a pre-specified colored vowel or consonant letter. In a first phase of the task, they repeatedly categorize the two letters (e.g., presented in green and blue) by responding to one of them on the basis of a pre-specified color (e.g., green). In a second phase the target color changes to a new color (e.g., purple) and the previous target color (e.g., green) becomes invalid. Thus, participants have to switch from one means (responding to green) to another means (responding to purple). In general, people's responses slow down when the new color is introduced, which reflects the costs of the switch.

In an important adaptation of the original set-shifting task, we varied the processing instructions during the first phase. Some participants represented their behavior in terms of the task goal (i.e., categorizing letters), while others represented their behavior in terms of the task means (i.e., responding to the target color). They received cues of these two levels of representation at the beginning of each trial of the first phase. Furthermore, participants were exposed to positive or neutral stimuli directly after the presentation of these cues, thereby implicitly increasing the motivation for the goal or the means (Custers & Aarts, 2005). Thus, we could test whether implicit motivation for the goal facilitates a switch from the old means to a new means, while implicit motivation for the means hampers a switch from the old means to another. Experiment 4.1 used the modified set-shifting task to provide an initial test of our hypotheses, and Experiment 4.2 was designed to replicate the results in a different (new) paradigm. Experiment 4.3 explored a boundary condition for rigidity in implicit motivation of goal-directed behavior.

Experiment 4.1

Method

Participants and design. Eighty two undergraduates (46 females; mean age 21.7 years) were randomly assigned to the cells of a 2 (first phase valence: positive vs. neutral) x 2 (representation: goal vs. means) between-subjects design.

Procedure and materials*.* Participants were told to perform a task in which they had to quickly and accurately categorize letters as vowels or consonants by means of responding to a pre-specified colored letter that was presented together with another colored letter on the screen. Instructions and stimuli were presented on a computer-screen. In addition, a left and a right key were assigned as response keys for vowels and consonants, and the two possible response-key mappings were counterbalanced across participants. Thus, participants learned that the goal was to categorize letters and that they had to do this by means of responding to the letter in a pre-specified color.

The imperative stimuli consisted of two simultaneously presented letters (A, E, O, U, K, M, R, and S) one above the other. The location of the target was determined at random, either above or below. The letters were always presented in two different colors, selected from a pool of three colors: green, blue or purple. Assignment of colors to stimuli (relevant, irrelevant, new) was counterbalanced across participants. Participants were instructed to respond to the letter appearing in a pre-specified color (e.g., relevant = green), which always appeared together with another letter in a constant different color (e.g., irrelevant = blue). After 40 trials participants had to switch to a new pre-specified color that had not appeared before (e.g., new = purple) and had to ignore the previously relevant color (e.g., green). For example, in the first 40 trials the two letters would always be green and blue, and if the target color was green the colors after the switch would be purple and green, where purple would be the new target color.

Participants were told that we were interested in how people perform cognitive tasks in settings of everyday life and to simulate these situations they would be presented with all kinds of everyday images during the task. In the goal representation condition participants were asked to represent their behavior in terms of the goal to categorize letters, and in the means representation condition they represented it in terms of the means of responding the target color. Accordingly, in the goal representation condition a cue appeared on the screen in the form of a gray square with the word ‘LETTERS’ in white in the middle of it, and in the means representation condition a gray square appeared with the target color word in white in the middle (i.e., ‘GREEN’, ‘BLUE’ or ‘PURPLE’). Thus, the cue LETTERS supported participants to keep focused on the goal to categorize letters, and the color cue kept them focused on the means to reach the goal (for a similar manipulation of levels of behavior representations, see van der Weiden, Aarts, & Ruys, 2010). The representation-cue was directly followed by a positive or neutral IAPS picture (Lang, Bradley & Cuthbert 1998), thereby enabling us to unobtrusively co-activate the goal (vs. means) representation with either neutral or positive affect. Participants were told that the task started with a first phase in which they had to respond to a specific color, but that at a later point in time they would have to respond to a different color and that a screen would announce this rule change by showing the new target color. They were also informed that after the switch the representation-cue would not be shown anymore.

There were 40 trials in the first phase. In Figure 4.1 the course of a trial and the time line of the experiment are shown. Each trial began with a blank screen (500 ms) followed by the representation-cue (250 ms), another blank screen (250 ms) and then a picture from the IAPS (250 ms) and a final blank screen (250 ms) appeared before the imperative stimulus was presented, which remained on the screen until a response was given. In order to present a unique picture in each trial, 40 IAPS pictures were selected at random from a pool of 60 positive (mean valence = 7.67, *SD* = 0.32) or a pool of 60 neutral pictures (mean valence = 4.89, *SD* = 0.39) dependent of the first phase valence condition. After a correct response a blank screen appeared for 1000 ms and then a new trial started. Feedback was given only for errors. After an incorrect response the word ‘Incorrect!’ would appear for 2000 ms instead of the blank screen. Stimulus presentation was completely randomized with one constraint: targets and distracters were always response incompatible (i.e., both mapped to different response keys). After the 40 trials of the first phase an instructional cue (3000 ms) announced the switch to the new color. There were 20 trials in the second phase. The representation-cues were replaced with blank screens and the 20 IAPS pictures were selected at random from the pool of 60 neutral pictures for all participants. Prior to the experimental task participants performed 30 practice trials (which included the representation-cues).

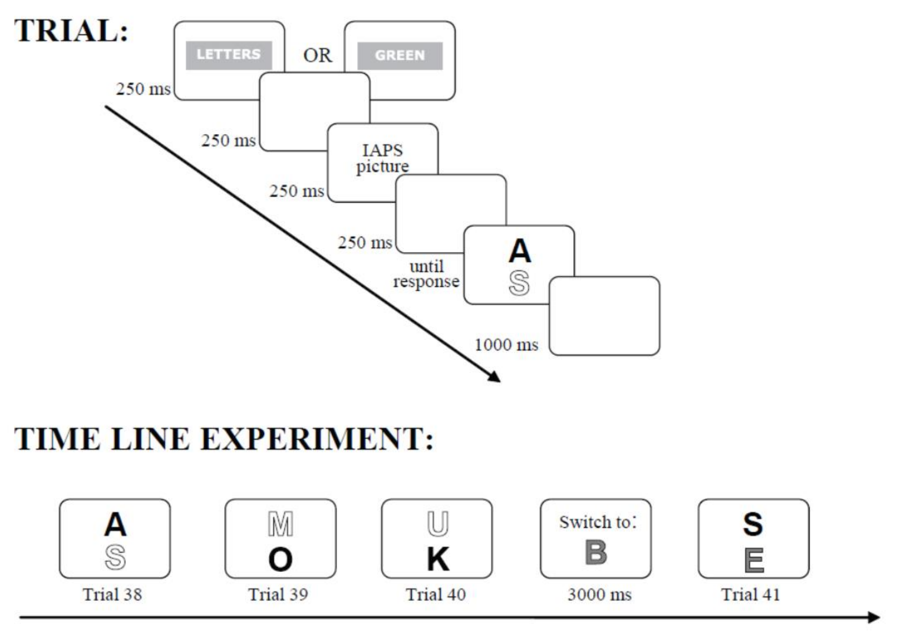

Figure 4.1. Example of a trial and the time line of Experiment 4.1. The colored letters are presented in black, white and gray as substitutes for green, blue and purple, respectively. The course of the trial at the top of the figure represents a correct trial in the first phase (for incorrect trials the final slide contained the word “Incorrect!” and lasted 2000 ms). The IAPS picture had either a neutral or a positive valence. The time line of the experiment is presented at the bottom of the figure and shows four critical trials around the switch (trials 38 to 41). The instructional cue was presented between trial 40 and 41 and lasted for 3000 ms. In this example

the target color before the switch is black (i.e., green) and after the switch is gray (i.e., purple).

Data preparation. Incorrect responses were excluded from analysis (mean errors = 7.5%). There were no significant differences on error rates between conditions. Responses exceeding 3 standard deviations from the mean reaction time were excluded from further analysis (0.37% of correct responses). There were no significant differences on the overall mean RT's between conditions. The critical comparison of mean reaction times is between the mean of five trials immediately before the switch and the mean of five trials immediately after the switch.[2] A difference score of these means was calculated and served as the dependent variable: switch cost.

Results and Discussion

Switch costs were subjected to a 2 (first phase valence: positive vs. neutral) x 2 (representation: goal vs. means) ANOVA. The analysis did not yield a main effect of first phase valence ($F<1$). Whereas the goal representation cue caused a slightly lower switch cost than the means representation cue, this main effect of representation was not reliable, $F(1, 78) = 2.96$, $p = .09$. More importantly, a significant interaction effect of First phase valence x Representation was found, $F(1, 78) = 8.56$, $p < .01$, $\eta^2 = .10$. The mean switch costs per condition are presented in Figure 4.2.

[2] Ideally, taking the reaction time of the trial immediately following the switch would be a good indicator of switching performance, but in our design we only had one such observation per participant making it a poor measure. Therefore, we chose to take the mean of five trials, which is mostly used in this type of task-switching paradigm because it produces a reliable measure of performance before and directly after the switch without losing power to detect effects of switching performance (e.g., Dreisbach & Goschke, 2004).

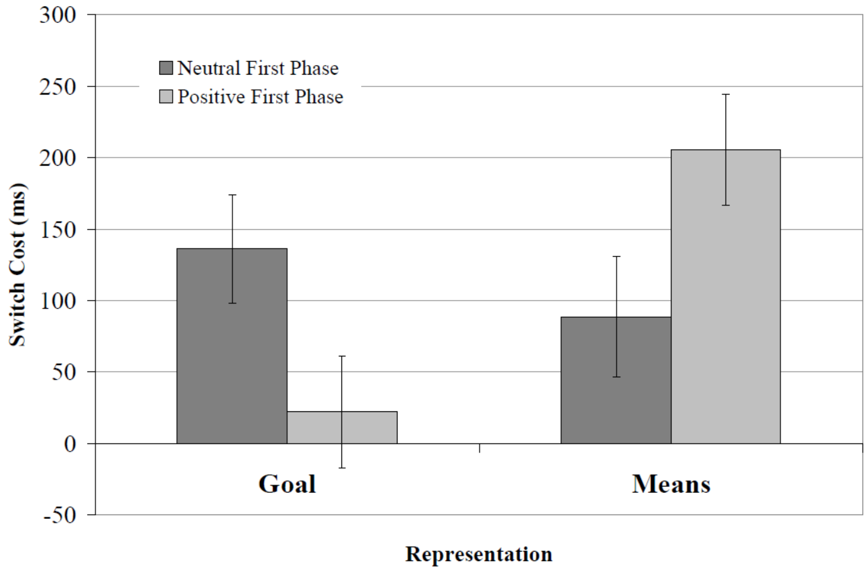

Figure 4.2. Main results of Experiment 4.1 are presented as switch costs in ms as a function of first phase valence (positive vs. neutral) and representation (goal vs. means), with error bars representing one standard error of the mean.

Simple effects analyses revealed that participants in the goal representation condition showed lower switch costs when they were in the positive first phase condition than when they were in the neutral first phase condition, $F(1, 78) = 4.52$, $p = .04$, $\eta^2 = .05$. In the means representation condition the effect was also significant but the other way around, indicating that participants in the positive first phase condition had higher switch costs compared to participants in the neutral first phase condition, $F(1, 78) = 4.60$, $p = .04$, $\eta^2 = .06$.

These effects on switch costs were not driven by differences by condition before the switch. The mean of five reaction times before the switch was significantly faster in the means representation condition, *F*(1,

78) = 6.52, p =.01, η^2 =.08, but this main effect of representation was not qualified by an interaction effect (F<1). Thus, when participants represented their behavior in terms of the goal to categorize letters, positive affect facilitated the switch to use a new color, but when they represented the behavior in terms of the means to respond to the color pre-specified in the first phase, positive affect hampered the switch to a new color means.

Experiment 4.2

The first experiment showed that attaching positive affect to the representation of the goal or the means motivates a more flexible or rigid mode of goal-directed behavior, respectively. However, although the modified set-shifting task produced the predicted pattern of results, the distinction between the goal (categorize letters) and the means (by responding to a pre-specified color) might appear somewhat artificial, even though we emphasized to participants that the task consisted of this goal and means. In line with this idea, research on action control suggests that most information processing tasks (including task switching tasks) can be composed of several cognitive representations that differ in their level of control (Hommel & Elsner, 2009). However, to offer more compelling evidence for our ideas we conducted a second experiment to replicate the previous findings in a different task that clearly speaks to the separation of a goal and means in goal-directed behavior. Specifically, instead of using the task of categorizing letters as vowels or consonants, we designed a task in which participants have the goal to turn on a light by means of pressing a specific button.

Method

Participants and design. Seventy undergraduates (42 females; mean age 21.9 years) were randomly assigned to the cells of a 2 (first phase valence: positive vs. neutral) x 2 (representation: goal vs. means) between-subjects design.

Procedure and materials. Participants worked on a computer task and were told that the goal of the task was to turn on a light bulb by means of pressing a pre-specified colored button. This button was presented either on the left side or the right side of the screen, together with another colored button that was presented on the opposite side. A left and a right key were assigned as response keys for the left and right locations.

The buttons were always presented in two different colors, selected from a pool of three colors: green, blue or purple. Assignment of colors to buttons (relevant, irrelevant, new) was counterbalanced across participants. Participants were instructed to press the button appearing in a pre-specified color (e.g., relevant = green), which always appeared together with another button in a constant different color (e.g., irrelevant = blue). After 40 trials participants had to switch to a new pre-specified color that had not appeared before (e.g., new = purple) and had to ignore the previously relevant color (e.g., green). The location of the target was determined at random, either left or right.

Depending on the condition participants were in, they were either told to represent their behavior in terms of turning on the light (goal representation), or in terms of pressing the target colored button (means representation). A specific cue was presented on the screen at the beginning of each trial to encourage participants to represent the behavior in terms of the goal or the means. In the goal representation condition the cue appeared on the screen in the form of a gray square with the words ‘TURN ON LIGHT’ in white in the middle of it, and (similar to Experiment 4.1) in the means representation condition the square appeared in gray with the words ‘PRESS GREEN’, ‘PRESS BLUE’ or ‘PRESS PURPLE’ in white in the middle of it. The cue was directly followed by the presentation of a positive or neutral IAPS picture.

There were 40 trials in the first phase. Each trial began with a blank screen (1000 ms) followed by the cue (500 ms), another blank screen (250 ms) and then a picture from the IAPS (250 ms) and a final blank screen (250 ms) appeared before a fixation cross (‘X’) was presented for 500ms. Then the two buttons were presented, which remained on the screen until a response was given. A lighted bulb appeared for 1000 ms after a correct response and after an incorrect response an unlighted bulb appeared. A new trial started after an interval of 2500 ms. After the 40 trials of the first phase an instructional cue (3000 ms) announced the switch to the new color. There were 20 trials in the second phase.

Data preparation. Switch costs were calculated the same way as in Experiment 4.1. Incorrect responses (mean errors = 1.3%) and outliers (0.43% of correct responses) were excluded from analysis. No differences between conditions in error rate were found, nor were there differences on the overall RT’s.

Results and Discussion

Switch costs were subjected to a 2 (first phase valence: positive vs. neutral) x 2 (representation: goal vs. means) ANOVA. The analysis did not yield a main effect of first phase valence ($F<1$). Whereas the goal representation cue caused a slightly lower switch cost than the means representation cue, this main effect of representation was not reliable, *F*(1,

66) = 1.74, p =.19. More importantly, the significant interaction effect of First phase valence x Representation was replicated, $F(1, 66) = 9.16$, p <.01, η^2 =.12, see Figure 4.3.

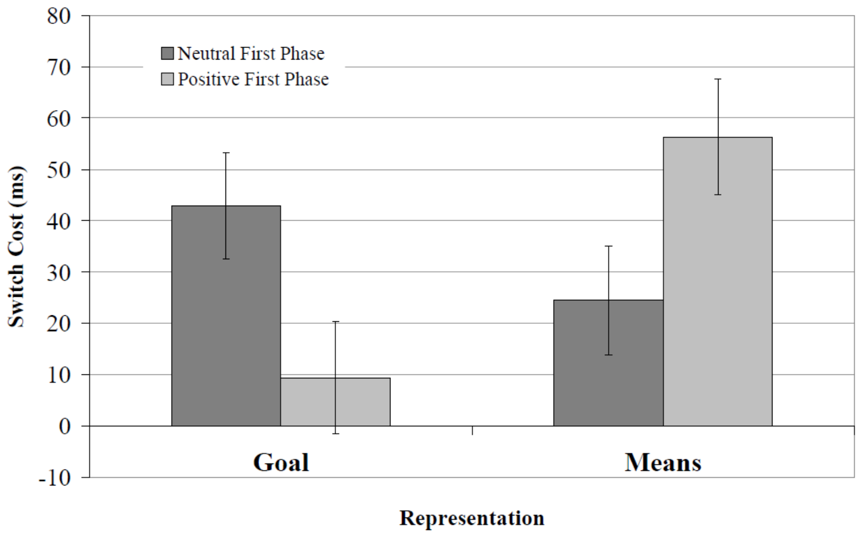

Figure 4.3. Main results of experiment 4.2 are presented as switch costs in ms as a function of first phase valence (positive vs. neutral) and action representation (goal vs. means). Error bars represent one standard error of the mean.

Simple effects analyses revealed that switch costs in the positive goal representation condition were lower when in the neutral goal representation condition, $F(1, 66) = 4.97$, p =.03, η^2 = .07. Switch costs in the positive means representation condition were significantly higher than in the neutral means representation condition, $F(1, 66) = 4.22$, p =.04, η^2 =.06.

These effects on switch costs were not driven by differences by condition before the switch, because there were no significant effects on the mean of five trials before the switch (all F's < 1.10). Thus, results of

Experiment 4.2 conceptually replicate the findings of Experiment 4.1 in a task (turning on a light by means of pressing a button) that more clearly speaks to the separation of a goal and a means in goal-directed behavior.

Experiment 4.3

Thus far, our data provide clear evidence that flexibility and rigidity is a function of the level of representation (goal or means) at which positive affect implicitly motivates people to control their behavior. Flexibility vs. rigidity reflected the ease vs. difficulty to abandon the practiced means (e.g., respond to green) and to switch to new means (e.g., respond to purple). These findings, however, are constrained to situations where the to-be-abandoned means is overtly present after the switch, and therefore is in direct competition with the new means as a result of attracting attention (cf. research on temptations and delay of gratification; Leander, Shah, & Chartrand, 2009; Mischel, Shoda, & Rodriguez, 1989). This raises the question whether the observed flexibility and rigidity is dependent on this direct attentional competition.

To explore this issue, in Experiment 4.3 we removed this direct overt attention competition, by presenting participants with two novel colors in phase 2 of the letter categorization task. Because task switching seems to be more strongly hampered by an attention process that relies on specific stimuli-response processing (Mayr & Bryck, 2007; Monsell, 2003), it is likely that implicitly motivating people on the means level in the absence of the overt attentional competition may lead to less switch costs. In this case, attention is no longer attracted to the means one is motivated to engage in, and hence the rigidity effect might (partly) disappear. However, our findings indicate that implicitly motivating people on the goal level renders a switch to other means less difficult, and this motivation to attain a goal is likely to promote and shield goal-directed processing in the absence of overt attentional competition (Custers & Aarts, 2010; Shah, Friedman, & Kruglanski, 2002). Therefore, attaching positive affect to the goal representation may leave flexibility of the switch unaffected when the old means is no longer overtly present.

Method

Participants and design*.* Eighty-three undergraduates (45 females; mean age 21.5 years) were randomly assigned to a 2 (first phase valence: positive vs. neutral) x 2 (representation: goal vs. means) between-subjects design.

Procedure and materials*.* The procedure and materials were similar as in Experiment 4.1, with one major adjustment. After the switch participants were presented with two completely new colors (red and yellow). Assignment of these colors to new target and new irrelevant was counterbalanced across participants.

Data preparation*.* Switch costs were calculated the same way as in the previous experiments. Incorrect responses (mean errors = 5.4%) and outliers (0.36% of correct responses) were excluded from analysis. No differences between conditions in error rate were found, nor were there differences on the overall RT's.

Results and Discussion

Switch costs were subjected to a 2 (first phase valence: positive vs. neutral) x 2 (representation: goal vs. means) ANOVA. The analysis did not yield a main effect of first phase valence, $F(1, 79) = 1.24$, $p = .27$. Whereas the goal representation cue caused a slightly lower switch cost than the means representation cue, this main effect of representation was not reliable, $F(1, 79) = 2.20$, $p = .14$. More importantly, there was a significant interaction effect of First phase valence x Representation, $F(1, 79) = 5.21$, $p < .03$, $\eta^2 = .06$, see Figure 4.4.

Simple effects analyses revealed that switch costs in the positive goal representation condition were lower than in the neutral goal representation condition, $F(1, 79) = 5.97$, $p = .02$, $\eta^2 = .07$. However, switch costs in the positive means representation condition were not significantly different from switch costs in the neutral means representation condition, $F<1$. Furthermore, there were no significant differences between conditions on the mean of five trials before the switch (all F's < 1).

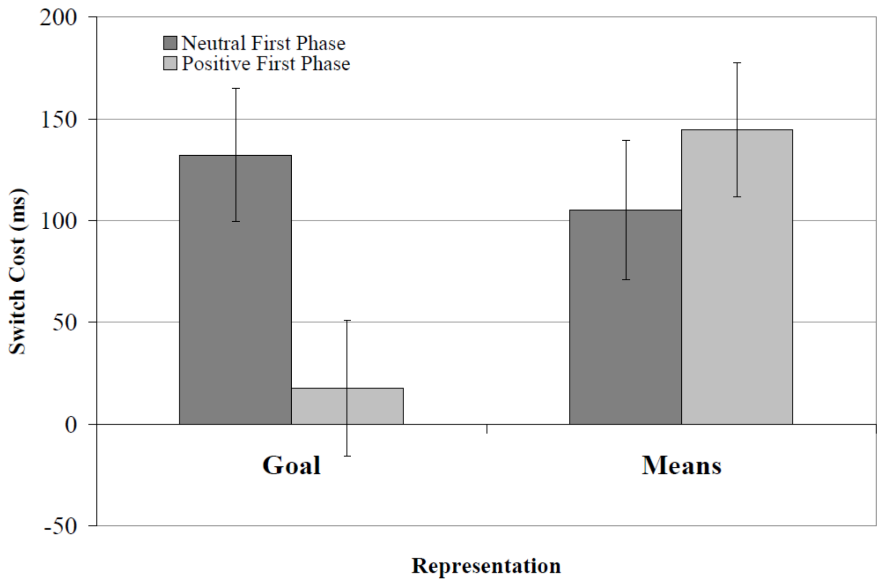

Figure 4.4. Main results of experiment 4.3 are presented as switch costs in ms as a function of first phase valence (positive vs. neutral) and action representation (goal vs. means). Error bars represent one standard error of the mean.

These findings again show that when goal-directed behavior is implicitly motivated at the goal level flexibility is enhanced. However, when goal-directed behavior was implicitly motivated at the means level and the means did no longer overtly attract attention we did not find increased rigidity. This suggests that control over behavior by the old means does not run in an offline fashion, but rather in an online fashion such that it occurs when there is a direct opportunity to execute the goal-directed action.

General Discussion

Based on the idea that positive affect can implicitly motivate the control of goal-directed behavior at different levels (Custers & Aarts, 2010), in three experiments we showed that positive affect facilitates flexibility (faster switch to new means) when attached to the goal representation, but fosters rigidity (slower switch to new means) when attached to the means. These effects rely on different functions of executive control within a specified goal-means structure, namely switching and focussing of attention and action (Dijksterhuis & Aarts, 2010). If positive affect is attached to the goal representation people are motivated to control their course of action to reach the goal, and become more flexible in switching to other means if such a switch is required to reach the goal. However, if people represent their behavior in terms of the means leading to the goal, positive affect motivates performance of that means, and therefore causes executive control to maintain focussed on the means. In other words, motivating instrumental actions by positive affect makes it more difficult to refrain from the actions, and thus to switch to new ones. Importantly, this rigidity mainly occurred when practiced means produced direct competition for attention with new means. Thus, whereas positive affect motivates people to be more flexible on the goal level, it motivates a rigid mode of responding on the means level when the means is overtly present. Together, our findings extend and integrate previous research on the role of positive affect in implicit motivation of goal-directed behavior (Custers & Aarts, 2005) with research on behavioral regulation and task switching as a function of the human capacity to represent behavior in terms of goals and means (Aarts et al., 2008; Meiran, 2010; Vallacher & Wegner, 1987).

The present findings are confined to a specified goal-means relation in a task at hand. It is important to note, though, that such relation is often part of a hierarchically ordered knowledge structure (Aarts & Dijksterhuis, 2000; Gallistel, 1985; Kruglanski et al., 2002; Vallacher & Wegner, 1987). This hierarchical nature renders people's tendency to represent their goal-directed behavior conditional on cognition and attention. Previous research shows that levels of behavior representation vary as a function of both context and individual differences and play a role in understanding own and others' behavior (Aarts, Gollwitzer, & Hassin, 2004; Kozak, Marsh, & Wegner, 2006; Trope & Liberman, 2010; Vallacher & Wegner, 1989; Wegner, Vallacher, Macomber, Wood, & Arps, 1984; Van der Weiden et al., 2010). Therefore, a means in one context might be considered a goal in another. For example, the act of commuting consists of the means of taking the car that leads to the goal of going to work. However, there are even lower means, such as turning left at the McDonald's, and this lower means turns the previous means representation into a goal. Moreover, going to the office can also be considered a means for an even higher level goal, such as preparing a lecture. The way people represent their behavior (in terms of goals or means) thus seems to rely on the context at hand. Accordingly, whereas our findings indicate that flexibility and rigidity in goal-directed behavior can result from the implicit motivation to control behavior at different levels, it may be essential to take this context into account to understand and predict when positive affect motivates a more flexible or rigid control of behavior.

Furthermore, we wish to stress that the interpretation of our findings is derived from specific paradigms where switching between means is an obligatory aspect of the task. Although this might render generalization to other situations difficult, there is some recent work that seems to be in line with the current results (Bayuk, Janiszewski, & Leboef, 2010). Specifically, participants who are in an abstract mind-set and have formed an intention to reach a certain goal show an increased willingness to pursue an alternate means to reach the goal. However, a concrete mind-set decreases willingness to pursue an alternate means. From the perspective of action identification theory these findings are in line with our results, because abstract high-level identities are characterized by action flexibility and concrete low-level identities are characterized by action rigidity (Vallacher & Wegner, 1987). The account we put forth here thus seems to be complementary to other accounts in the literature, such as those of concrete versus abstract mind-sets, on condition that these mind-sets also produce effects by their motivational value for the person (Clore & Huntsinger, 2007).

To conclude, we observed that positive affect motivates people to be rigid or flexible in goal-directed behavior, but this depended on how people represented their behavior—in terms of higher level goals or lower level means. We therefore believe that taking into account whether people represent their behavior in terms of goals or means promotes a better understanding of how behavior is implicitly motivated and regulated towards goal attainment.

Chapter 5

The interactive role of action-outcome learning and positive rewarding information in motivating goal-directed behavior

Abstract

Human action is goal-directed and thus aimed at obtaining desired outcomes. The ability to direct behavior towards outcomes arises when people have learned that their own actions lead to specific events. It is assumed that goal-directed behavior gains motivational properties when the outcome is associated with positive signals and thus outcomes serve as incentives or rewards. This study explores the potential building blocks of motivated goal-directed behavior by examining how action-outcome learning interacts with positive affective signals in motivating people to obtain outcomes. In a learning paradigm, an object was displayed either after or before the participant pressed a key, so that the object represented an outcome of action or not. The object was implicitly paired with neutral or positive auditory signals. Results showed that experienced wanting and actual effort to obtain the object was enhanced when the object represented an outcome of action and was co-activated with a positive signal. Overall these findings suggest that motivated goal-directed behavior is supported by an implicit process in which action-outcome learning interacts with reward value information.

This chapter is based on: Marien, H., Aarts, H., & Custers, R. (2014). *The interactive role of action-outcome learning and positive rewarding information in motivating goal-directed behavior.* Manuscript submitted for publication.

Most human actions are goal-directed and are thus aimed at producing desired outcomes in the environment. For example, a simple click of the left mouse button can open an e-mail message from a colleague, and pulling a kitchen drawer can be directed at grabbing utensils for dinner. Human goal-directed behavior is thought to result from the brain's capacity to predict future events that are caused by actions, so that actions, such as clicking a mouse, can be readily selected to produce desired outcomes, such as reading an e-mail message (Schacter, Addis, & Buckner, 2007; Suddendorf & Corballis, 2007). The control of goal-directed behavior thus requires knowledge about the relationship between outcomes and actions that produce them (Bandura, 1986; Hommel, 2013; Skinner, 1996).

Although action-outcome information supports the control of goal-directed action, it does not necessarily motivate behavior. Attaining goals is not always easy; it often requires effort investment to obtain the desired outcome. To determine whether a given outcome is worth the expenditure of effort, people are equipped with the ability to assess the desirability of the outcome (Dolan, 2002; Shizgal, 1999). The basis for the assessment of desirability of outcomes arises from the processing of positive affective information that can come from different sources and signals, such as positive mood (Aspinwall, 1998; van Wouwe, Band, & Ridderinkhof, 2011), monetary gains (Heitz, Schrock, Payne, & Engle, 2008; Müller et al., 2007), or positive words or pictures (Aarts & van Honk, 2009; Custers & Aarts, 2005; Gable & Harmon-Jones, 2008). Recent research suggests that desirability is enhanced when positive signals accompany the mere activation of action-outcome concepts (Custers & Aarts, 2010). This implicit affective-motivational process supports goal-directed behavior in mobilizing effort, such that an outcome attached to a positive signal serves as an incentive or reward. This concurs with modern animal learning research in which strict behaviorist's approaches to stimulus-response learning (Skinner, 1953; Watson, 1925) are complemented with the view that the value an individual assigns to action-outcomes as a result of positive affective experiences with the outcome is a key to the motivational control over goal-directed behavior (Berridge, 2001; Bindra, 1974; Bolles, 1972; Dickinson & Balleine, 1995).

Previous research on the impact of positive rewarding signals on stimulating goal-directed behavior has mainly focused on instructed or cued outcomes and does not often distinguish between outcomes and their rewarding properties (Dickinson & Balleine, 1994; Dijksterhuis & Aarts, 2010). This leaves open the question of whether action-outcome learning plays a crucial role in the way in which positive rewarding signals motivate behavior. On other occasions, rewards are used as behavioral outcomes that can be obtained (e.g., when the outcome is food under conditions of hunger), which suggests that reward signal processing is sufficient for goal-directed motivation to occur. Here we propose that motivated goal-directed behavior may result from a learning process in which action-outcome information and positive affective signals interact in implicitly producing wanting and effort to obtain the desired outcome or goal (Marien, Aarts, & Custers, 2013). Specifically, motivated goal-directed behavior is hypothesized to be more likely to arise when action-outcome information is co-activated with positive affective signals. We report three experiments to test this hypothesis.

The process of action-outcome learning is central to the theoretical approach of the ideomotor principle (Hommel, Müsseler, Aschersleben, & Prinz , 2001; Shin, Proctor, & Capaldi, 2010). Basically, the ideomotor principle holds that actions are represented in terms of their perceptual results, which grounds cognitive action representations in perception. Furthermore, a link between action and outcome is formed when the outcome follows a motor movement. This link is assumed to be bidirectional, such that activating the outcome representation (e.g., by the mere anticipation or priming of the outcome) readily selects the action to produce the outcome. The ideomotor principle further suggests that goal-directed behavior evolves from simple movement goals to more complex social goals that are accessed in different contexts by the same mechanisms underlying action-outcome learning (Maturana & Varela, 1987). Thus, we first learn to orchestrate our motor movements before we can effectively pull the kitchen drawer and take out utensils for dinner. Eventually specific learned patterns of motor movements become associated with outcomes in terms of sensory/perceptual and semantic/cognitive codes (Aarts & Veling, 2009; Kray, Eenshuistra, Kerstner, Weidema, & Hommel, 2006; Pulvermüller, 2005; Lindemann, Stenneken, van Schie, & Bekkering, 2006). Indeed, it has been shown that sensory-motor goal representations (acquired in goal-directed motor tasks) generalize to abstract features of outcomes, such that action-outcome representations can become socially meaningful and carry affective information (Beckers, De Houwer, & Eelen, 2002).

Ideomotor theorizing provides a parsimonious framework to understand how action-outcome knowledge is acquired and involved in the selection and control of action. However, although the ability to bind specific features of actions and outcomes together into more abstract or socially meaningful codes and to anticipate forthcoming outcomes to select associated actions is clearly an adaptive capacity, it may not be sufficient for successful adaptation in a changing environment. For more effective control of action in an unstable environment individuals may need to mobilize effort, or change the course of action to enhance the likelihood of bringing the desired outcome closer to themselves. Such effort mobilization and flexibility in action point to the importance of specifying when and how action-outcome knowledge turns into incentives and motivate behavior in rewarding contexts.

Recent research has started to explore this issue by examining the role of action-outcome information and positive affective signals in motivated goal-directed behavior (Aarts, Custers, & Marien, 2008; Custers & Aarts, 2005; Marien, Aarts, & Custers, 2012). This research relies on the notion that the ideomotor principle generalizes to more abstract action-outcome learning and socially meaningful behavior concepts (Hommel et al., 2001), and combines insights from studies on evaluative conditioning (De Houwer, Thomas, & Baeyens, 2001) and incentive learning (Dickinson & Balleine, 1995) to test whether modifying the valence of behavior concepts increases the motivation and control of the behavior. For instance, in one study it was demonstrated that subjects squeezed harder in a handgrip after repeated co-activation of the concept of physical exertion with positive affective signals (i.e., positive words) in a learning phase (Aarts et al., 2008). Furthermore, the mere activation of the concept of physical exertion facilitated faster initiation of the action, but did not lead to effortful behavior unless positive signals were attached to it. Similar results have been reported for the concept of academic achievement (Capa, Cleeremans, Bustin, & Hansenne, 2011; Capa, Cleeremans, Bustin, Bouquet, & Hansenne, 2011) and dieting (Köpetz, Faber, Fishbach, & Kruglanski, 2011).

The research alluded to above offers evidence for the interactive function of action-outcome information and positive affective signals in motivated goal-directed behavior. However, it is important to note that this research capitalizes on the notion that the participants considered the behavior concepts under investigation (e.g., physical exertion, academic achievement) as an outcome of action. Therefore, it can only be assumed that the increase in motivation and control of behavior was the result of acquired knowledge about an outcome of action and the pairing with positive affect. It is thus important to also incorporate the action-outcome learning process in the acquisition phase to provide more conclusive evidence for this notion.

Present research

For this purpose, we developed an action-outcome learning paradigm that simulates the process by which people learn to represent their actions in terms of outcomes and to associate the outcomes with positive affective signals. The paradigm allows us to manipulate whether an object appearing on the computer screen is conceived of as an outcome of an action or not by asking participants to press the spacebar before or after the presentation of the object. The paradigm further allows us to manipulate the rewarding value of the object by presenting positive (or neutral) auditory stimuli (words as 'good' or 'nice') upon visual presentation of the object that are central to the human nature of social learning and reinforcement (Bandura, 1986; Miller & Dollard, 1941). The paradigm, then, enables us to scrutinize the combined role of action-outcome information and reward signal processing in motivated goal-directed behavior (the motivation to obtain a desired outcome) by dissociating the action-outcome learning process from the outcome-reward value learning process (Marien et al., 2013).

The first experiment was designed to provide initial support for the suggestion that experienced motivation (or wanting) to obtain an object can be enhanced by co-activating the object with positive affective signals. Crucially, this enhanced motivation is expected to mainly occur if the objects are conceived of as outcomes of actions. Specifically, experienced motivation to obtain the object will be enhanced when the presented object is co-activated with a positive affective signal and follows (vs. precedes) the participant’s action.

In Experiments 2 and 3 we address the motivational quality of behavior as a function of action-outcome learning and positive signal processing. To properly assess the motivational quality it is important to take the principle of resource conservation into consideration. According to motivation intensity theory the investment of effort is determined by the difficulty of activity that must be carried out to attain desired outcomes (Brehm & Self, 1989; Gendolla, Wright, & Richter, 2011). Hence, as long as effort allocation is worthwhile it will correspond with the perceived difficulty of the task. However, when difficulty or demand of the task is unclear effort investment is proportional to potential motivation (Richter & Gendolla, 2006; 2007; 2009), that is the upper limit of the amount of effort a person is willing to exert (Wright, 2008). Here we test that potential motivation for goal-directed behavior is only increased when action-outcome information is paired with positive reward signals. Thus creating action-outcomes and linking them to positive reward signals renders behavior more effortful to attain the outcome. In the second experiment it was tested whether this enhanced motivation translates into effortful goal-directed behavior when task demands are left unclear. The third experiment tested whether the induced goal-directed behavior intensifies when the task is clearly more demanding to provide further evidence that motivation of goal-directed behavior is the result of the interaction between action-outcome learning and exposure to positive signals.

Experiment 5.1

In the first experiment the combined role of action-outcome learning and positive signal processing in motivating goal-directed behavior was examined by submitting all participants to a set of trials that each consists of a learning phase and a test phase. In the learning phase participants had to execute an action (pressing the spacebar) that was either preceded or followed by a neutral object on the computer-screen (e.g., the word “scissors”). The object was accompanied by a neutral or positive word spoken through headphones (e.g., the word “with” or “nice”). Thus after the learning phase, the display of the object could be conceived of as an outcome of an action or not, and this outcome representation was paired with a positive signal or not. After the acquisition phase participants were asked to indicate whether they currently wanted to obtain the object or not. The percentage of “yes” responses served as a measure of wanting (Custers & Aarts, 2005).

Method

Participants and design. Thirty-nine undergraduate students (16 male; mean age 21.6) participated in the experiment with a 2 (Object Presentation: no-outcome vs. outcome) X 2 (Shaping: neutral vs. positive) repeated measures design, in exchange for course credit or a small fee.

Stimuli. In a pilot study (*N*=30) undergraduates indicated how negative or positive they evaluated various objects. On the basis of this pilot study we selected 20 neutral objects: 10 office objects (e.g., *pencil, scissors*; *M*=5.5, *SD*=0.4, on a 9-point scale) and 10 musical instruments (e.g., *flute, tuba*; *M*=5.9, *SD*=0.9). These objects thus composed the stimuli (presented visually as words) that were used to manipulate the outcome presentation status (no-outcome vs. outcome) of the action.

On the basis of another pilot study (*N*=35) we also selected 5 neutral words (e.g.*, with, there*; *M*=4.6, *SD*=0.6) and 5 positive words (e.g., *beautiful, fun*; *M*=7.8, *SD*=0.9). These words were presented through headphones and were spoken by a realistic computerized female voice to manipulate the shaping status (neutral or positive) of the object (see appendix for description of all stimuli).

Procedure. Participants worked in separate cubicles in which the experiment was presented on a 60-Hz computer screen. They were told that they participated in an experiment that was designed to examine how people perform simple actions in the presence of visual and auditory information that can occur at different moments in time. Participants were informed that they had to perform a number of trials and that each trial consisted of 2 parts.

In the first part participants were presented with a series of random letter strings (e.g., FHTRBNMSP, all consonants) and were instructed to press the spacebar whenever they heard a tone presented through the headphones. They were informed that a word of an object would be presented on the computer screen either after or before they pressed the spacebar. Thus the object either appeared on the screen as a result of their own action or not. They were also informed that spoken words would be presented through the headphones simultaneously with the presentation of the objects.

In the second part of the trial participants were simply asked whether they wanted to have the presented object or not. They were asked to indicate this by means of fast responses and not to think too long about it.

After reading these instructions participants practiced the first part 4 times. After this instruction participants practiced the second part 4 times and after that they practiced a combination of the two parts 4 times. Practice was done with 4 objects (2 office objects, i.e., *pencil* and *compasses*; and 2 musical instruments, i.e., *trombone* and *triangle*) obtained from the pilot study. The remaining 16 objects were used for the actual experimental trials. Then participants performed 16 experimental trials, 4 objects determined completely at random for each of the 4 conditions, presented in a randomly determined order.

Trials. Each trial consisted of two parts: a learning phase and a wanting measure. To vary the object presentation manipulation (no-outcome vs. outcome) there were two types of learning phase trials (see Figure 5.1).

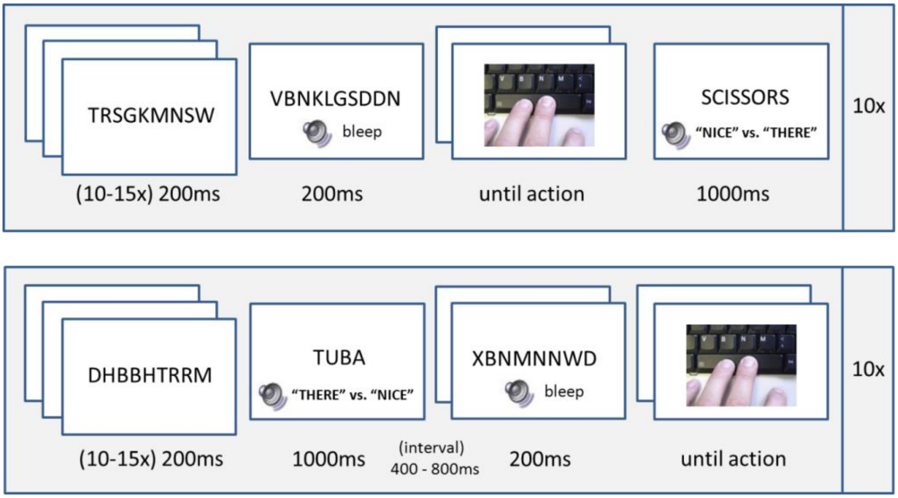

Figure 5.1. Examples of trials in the learning phase for the outcome presentation condition (top panel) and the no-outcome presentation condition (bottom panel).

Learning phase. A stream of random letter strings was presented on the screen. Each letter strings was presented for 200ms, and 10 to 15 (randomly determined) letter strings appeared on the screen. Next:

In the no-outcome condition an object word appeared on the screen for 1000 ms and simultaneously a spoken neutral or positive word (depending on shaping condition) was presented through the headphones. This was followed by 1 to 5 (randomly determined) letter strings. Then a tone was presented (4400Hz) for 200ms, which was the cue for participants to press the spacebar with their left hand. The stream of letter strings would continue until a response was detected followed by a blank screen (1500ms).

In the outcome condition a tone (4400Hz) was presented for 200ms, which was the cue for participants to press the spacebar with their left hand. The stream of letter strings would continue until a response was detected. As a result (or outcome) of pressing the spacebar an object word appeared on the screen for 1000ms and simultaneously a spoken positive or a neutral word (depending on shaping condition) was presented through the headphones. Then a blank screen (1500ms) was presented.

After that, the stream of random letter strings would start over. This sequence was repeated 10 times, thus participants had to press the spacebar a total of 10 times and this action was either consistently preceded (no-outcome) or followed (outcome) by the presentation of the same object word. Within a trial each of the 5 neutral or positive words was presented twice.

Wanting measure. After the learning phase (consisting of 10 sequences) the object word was presented on the screen and participants indicated whether they wanted to obtain this object (“yes”=1 and “no”=0). They could press the left and right arrow keys with their index finger and ring finger of their right hand, respectively. The left arrow key pointed at the option of a ‘no’ response and the right arrow key pointed to the option of a ‘yes’ response. The wanting measure consisted of the proportion ‘yes’ responses across the four trials in each of the four conditions.

It should be noted that motor responses (left hand) during the learning task differed from motor responses (right hand, right ring finger) to assess wanting (see also Expt. 2 and 3 for a similar approach). This incompatibility between motor responses for learning and wanting was implemented to ensure that effects cannot be attributed to mere response priming of the outcome (cf., Elsner & Hommel, 2001).

Debriefing. After the experiment participants were debriefed. Debriefing showed that none of the participants figured out the hypothesis of the study. There were 17 participants who indicated that the valence of the auditory words influenced their wanting responses. However, there was no three-way interaction when this conscious influence measure was added as a between-subjects factor ($F < 1$).

Results

The proportions of 'yes' responses of the wanting measure were subjected to an Object Presentation (no-outcome vs. outcome) X Shaping (neutral vs. positive) repeated measures ANOVA.

The analysis yielded a main effect of Shaping $F(1, 38) = 9.43$, $p = .004$, $\eta^2 = .20$. The main effect of Object Presentation was also significant, $F(1, 38) = 4.87$, $p = .033$, $\eta^2 = .12$. More important, a significant interaction effect of Object Presentation x Shaping was found, $F(1, 38) = 7.78$, $p = .008$, $\eta^2 = .17$ (see Figure 5.2).

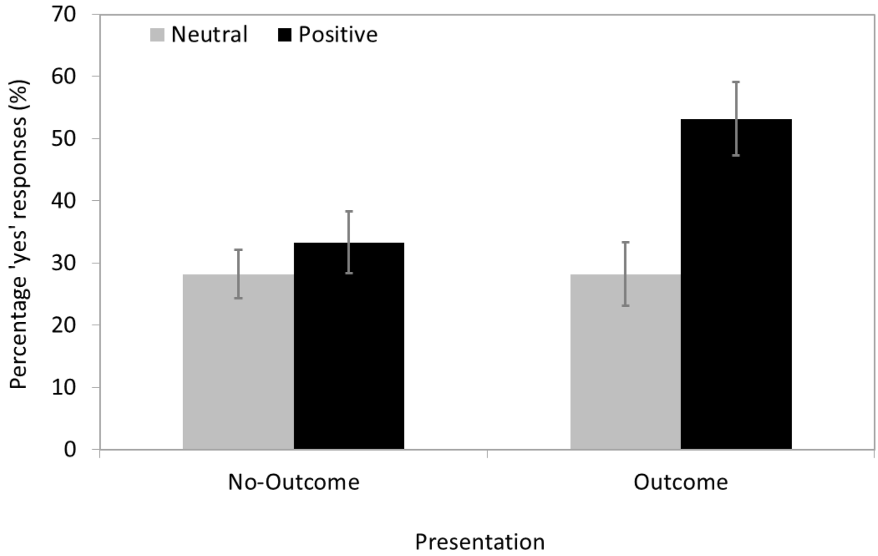

Figure 5.2. Results of Experiment 5.1: The percentage of 'yes' responses of the wanting measure as a function of object presentation and shaping.

Simple main effect analyses revealed that participants wanted to obtain objects more strongly in the positive outcome presentation condition (*M*=53.2%, *SD*=37) than objects in the neutral outcome presentation condition (*M*=28.2%, *SD*=32), F (1, 38) = 18.53, $p < .001$, $\eta^2 = .33$. There was no difference between the positive no-outcome presentation condition (*M*=33.3%, *SD*=31) and the neutral no-outcome presentation condition (*M*=28.2%, *SD*=24), (F <1).

Discussion

The findings of Experiment 5.1 provide initial support for our hypothesis that action-outcome learning interacts with reward signal processing in enhancing the motivation to obtain the outcome. Specifically, our data suggest that people become more strongly motivated to obtain an object when the object serves as an outcome of action and is attached to positive affect. Interestingly, whereas a subset of the participants indicated that the positive affective information might have influenced their wanting reports, the absence of the three-way interaction including the conscious influence measure suggests that the effects on self-reported wanting result from an implicit process in which the interactive function of outcome information and positive signals seems to operate without being fully aware of it.

Experiment 5.2

The purpose of Experiment 5.2 was to investigate whether the induced experienced motivation would also translate into effortful goal-directed behavior. To measure this, we designed a task that exploits one of the hall marks of goal-directed motivation: The speed of decreasing the distance between the desired outcome and oneself (e.g., Carver & Scheier, 1998). Specifically, in this task participants were presented with the object on the screen and had to press another key repeatedly, thereby creating the impression of moving the object closer to the front of the screen. Furthermore, the behavioral task allowed us to distinguish between two action components that play a role in motivated goal-directed behavior (Aarts et al., 2008). The first component comprises the initiation of action (i.e. the speed of starting), which can be considered as a measure of the ease of action production in response to exposure of the outcome as a result of previous action-outcome learning. The second component comprises the effort mobilization (i.e. the speed of completing the task), which should be sensitive to the motivation to obtain the desired action-outcome. Because the demands of the behavioral task are assumed to be unclear, effort mobilization is proportionate to the potential motivation to obtain the object (Richter & Gendolla, 2006). Thus, effort mobilization results in faster repetitive action in our task of moving the object to the front (cf. Bijleveld, Custers, & Aarts, 2012a; Treadway et al., 2012). Accordingly, it is expected that participants will mobilize effort to speed up action to bring the object to the front when the object has been learned to be an outcome of action and is associated with a positive affective signal.

Method

Participants and design. Forty undergraduate students (21 male; mean age 22.5) participated in the experiment with a 2 (Object Presentation: no-outcome vs. outcome) X 2 (Shaping: neutral vs. positive) repeated measures design, in exchange for course credit or a small fee.

Stimuli. These were exactly the same as in Experiment 5.1.

Procedure. Procedure was similar to that of Experiment 5.1 except for the second part of the trials. In the second part of a trial the object word that was presented in the first part would appear at the end of a hallway and participants were instructed to press the down arrow key 20 times in a row, thereby moving the object to the front of the hallway. After each press the word would be enlarged and so it appeared as if the object was brought closer to the participant.

Trials. Each trial consisted of two parts: a learning phase and a behavioral task. The learning phases were exactly the same as in Experiment 5.1.

Behavioral task. After the learning phase (consisting of 10 sequences) a hallway was presented for 1000ms (cf. Markman & Brendl, 2005). This marked the start of the second part of the trial. Then the same object-word as presented in the learning phase was presented at the end of the hallway (see Figure 5.3). Participants had to press the down arrow key with their right index finger . After each button press the font size of the letters was increased with 3 points (ranging from font size 18 to 75) and the vertical position was shifted downward with 5 pixels (ranging from y position 205 to 300 on an 800x600 screen resolution). The hallway remained stationary and thus the impression was created that the object was brought closer to the participant by means of tapping on the down arrow. After 19 button presses the object-word reached its maximum position and the 20th button press caused the word and the hallway to disappear and a blank screen was presented for 1000ms. In this task the response latency of the first button press is used to assess the first component of goal-directed behavior: the initiation of action. The response latencies of the subsequent 19 button presses are used to index the second component of motivated goal-directed behavior: effort mobilization.

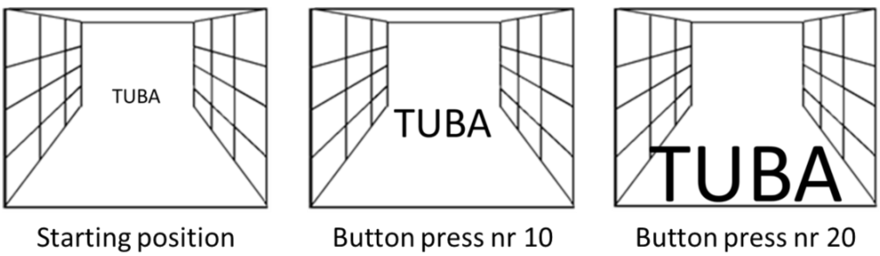

Figure 5.3. Example of behavioral task in Experiment 5.2. An object word appears at the end of a hallway and participants are instructed to bring the word to the front of the hallway by pressing the down arrow key 20 times in a row.

Data preparation. To reduce the impact of incidental slow starts, response latencies of the first button presses that were slower than 3 SD above the mean per condition were treated as outliers and therefore removed from analyses (2.97% of trials). Furthermore, analyses on all the remaining response latencies (2^{nd} to 20^{th} button presses) were performed on log-transformed data to reduce the impact of incidental slow latencies during completion of the task and also because the distribution was positively skewed (s>1). For the sake of clarity, we report non-transformed means.

Debriefing. At the end of the experiment participants were debriefed. The debriefing showed that none of the participants figured out the true hypothesis of this study. Although nearly half of the participants (n = 21) indicated that the valence of the auditory words influenced their performance on the behavioral task, similar to Experiment 5.1 the three-way interaction with this between subjects factor was absent (F <1). The nonexistence of the three-way interaction suggests that if effects on effortful behavior emerge they seem to occur in the absence of full awareness of the interactive operation of outcome information and positive signals.

Results

Action initiation. Average response times of the first button press were subjected to an Object Presentation (no-outcome vs. outcome) X Shaping (neutral vs. positive) repeated measures ANOVA. The analyses of the first response latency yielded a main effect of Object presentation, $F(1, 39) = 6.16$, $p = .017$, $\eta^2 = .14$; participants were faster in starting the behavioral task in the Outcome presentation condition (M = 381 ms, SD =

217) compared to the No-outcome presentation condition (*M* = 471 ms, *SD* = 382). Both the main effect of Shaping (*F* <1) and the interaction effect were not significant, *F*(1, 39) = 1.09, *p* = .30.

Effort mobilization. The average response latencies of the next 19 button presses per condition were subjected to a Time (2nd to 20th button press) X Object Presentation (no-outcome vs. outcome) X Shaping (neutral vs. positive) repeated measures ANOVA. The analyses of the average response latency of these 19 button presses yielded a main effect of Time, *F* (1, 39) = 20.59, *p* < .001, η^2 = .35, showing that participants generally slowed down during the behavior task. The main effect of Shaping was also significant, *F* (1, 39) = 4.73, *p* = .036, η^2 = .11; participants moved the object faster to the front of the hallway in the positive condition (*M* = 143 ms, SD = 28) than in the neutral condition (*M* = 147 ms, SD = 33). However, a significant interaction effect of Object presentation x Shaping was also found, *F* (1, 39) = 4.23, *p* = .046, η^2 = .10 (see Figure 5.4). No other main and interaction effects were significant (*F*'s < 1.34).

Tests for simple main effects revealed that object words in the positive outcome presentation condition (*M* = 142 ms, *SD* = 27) were moved faster to the front than object words in the neutral outcome presentation condition (*M* = 148 ms, *SD* = 35), *F* (1, 39) = 11.39, *p* = .002, η^2 = .23. There was no difference between the positive no-outcome presentation condition (*M* = 144 ms, *SD* = 31) and the neutral no-outcome presentation condition (*M* = 146 ms, *SD* = 31), *F* <1.

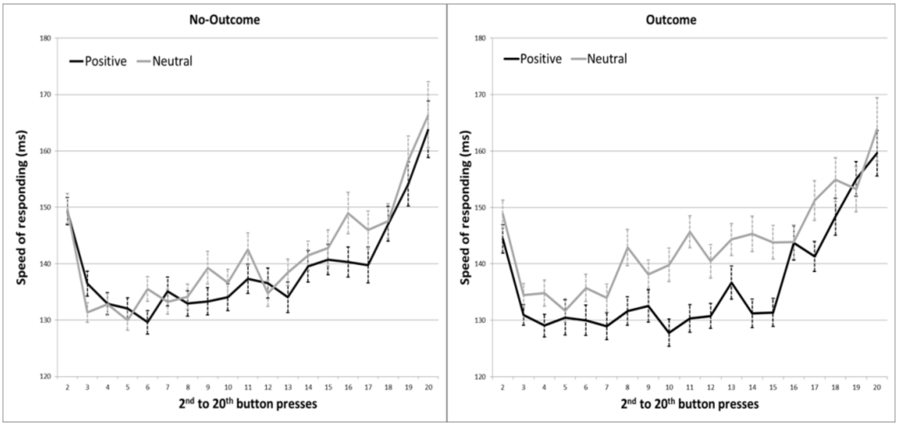

Figure 5.4. Results of Experiment 5.2: Speed of responding (in ms) across the 2nd to 20th button presses as a function of Object presentation and Shaping.

Discussion

The results of Experiment 5.2 are in line with the expectation that objects induce motivated goal-directed behavior when they are presented as an outcome of action and are associated with positive reward signals. Action-outcome learning was found to readily facilitate action production in that the behavioral task was initiated faster upon presenting the outcome, thus suggesting that the objects indeed were learned to serve as outcomes when they followed (rather than preceded) the action (cf. Elsner & Hommel, 2001). Importantly, after the first button press participants only mobilized effort to speed up responding on the next 19 button presses when the outcome was accompanied with positive reward signals. This suggests that participants were willing to put more effort in obtaining these objects by bringing them to the front of the hallway and thus closer to themselves.

Experiment 5.3

Experiment 5.3 was conducted to offer more compelling evidence for the idea that the findings of Experiment 5.2 are due to an increased effort allocation by the positively shaped outcome. According to motivation intensity theory effort allocation is determined by the difficulty of the task that must be carried out to attain the outcome (Brehm & Self, 1989; Gendolla, Wright, & Richter, 2011). In Experiment 5.2 the demands of the behavioral task were left unclear and the absolute level of effort intensity was assessed. Hence, we demonstrated effects of potential motivation on invested effort. To more fully support the account that positively shaped action-outcomes indeed caused participants to allocate more effort to attain the outcome it needs to be shown that the effect of speeded responding is dependent on the effort requirement of the behavioral task. Therefore, in the third experiment effort intensity will be measured relative to different demand levels. More specifically, in Experiment 5.3 the difficulty of the behavioral task is manipulated within participants to test the effect of enhanced effort requirement. As a consequence, the effect of positive shaping of the outcome on speeded responding should be more pronounced in the difficult version of the task.

Method

Participants and design. Fifty-three undergraduate students participated in the experiment. Six participants claimed to have already participated in the previous experiments and were excluded from further analysis. The remaining 47 participants (19 male; mean age 20.6) participated in the experiment with a 2 (Task difficulty: easy vs. difficult) X 2

(Shaping: neutral vs. positive) repeated measures design, in exchange for course credit or a small fee.

Stimuli. These were exactly the same as in Experiment 5.1.

Procedure. Procedure was similar to that of Experiment 5.1 with two exceptions. Firstly, we only included the learning phase for the outcome presentation. Secondly, participants were given extra instructions about the two difficulty levels of the behavioral task. The relatively easy version (i.e., the 1-finger task) was the same as the behavioral task in Experiment 5.2, except that they had to press the 1 key on the numerical keyboard instead of the down arrow to bring the object word closer to themselves. Participants were also instructed about the relatively difficult version of the task (i.e., the 2-fingers task) and were told that on some trials they had to simultaneously hold the 2 key while pressing the 1 key 20 times in a row. Participants further learned that at the beginning of each trial a cue would be presented indicating which version of the stimulus approach task was coming up. Participants practiced both the 1-finger task and the 2-fingers task 4 times. A pilot study (N=25) clearly showed that in the 1-finger condition participants were faster, and perceived the behavior task to be more easy to perform than in the 2-fingers condition.

Trials. Each trial consisted of two parts: a learning phase and the behavioral task. The learning phase was exactly the same as the learning phase for the outcome representation condition.

Behavioral task. There was a 1-finger and a 2-fingers version of the behavioral task. In the 1-finger task participants had to press the 1-key of the numerical keyboard 20 times with their right index finger to bring the word to the front of the hallway. In the 2-fingers task participants had to simultaneously hold the 2-key while pressing the 1-key 20 times. Before each trial a cue was presented for 2000 ms, indicating whether participants had to hold the 2-key for the upcoming task or not (see Figure 5.5). Then the hallway would be presented and the behavioral task would proceed in the same way as in Experiment 5.2. It is important to note that the hallway would only be presented if participants were already holding the 2-key in the 2-finger task. When participants failed to keep holding the 2-key, the trial would be immediately aborted and a feedback screen would be presented which said: “you released the 2-key”. This occurred very rarely (0.93%) and these trials were omitted from further analyses. The behavior task was performed in the presence of the experimenter to monitor that the participant conducted the task according to instructions.

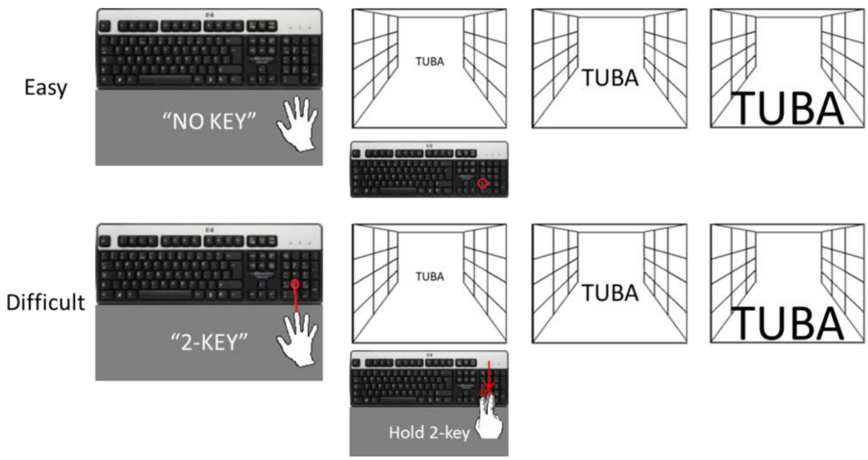

Figure 5.5. The easy and the difficult version of the behavioral task in Experiment 5.3.

Data preparation. Response latencies on the first button press that were slower than 3 SD above the mean were treated as outliers and therefore removed from analyses (1.33% of trials). Furthermore, analyses on all the remaining response latencies (2^{nd} to 20^{th} button presses) were performed on log-transformed data to reduce the impact of incidental slow latencies and also because the distribution was positively skewed (s>1). For the sake of clarity, we report non-transformed means.

Manipulation checks. At the end of the experiment a short questionnaire was administered in which participants had to respond to 8 items. Specifically, participants indicated on a scale from 1 (not at all) to 9 (very) how difficult, effortful, challenging and how much fun the behavioral task was for the 1-finger and the 2-finger version of the task.

Results

Manipulation checks. The 2-fingers task (M = 3.45, SD = 2.21) was reported to be more difficult than the 1-finger task (M = 2.15, SD = 1.44), F (1, 46) = 22.50, p < .001, η^2 = .33. The 2-fingers task (M = 3.06, SD = 1.99) was also perceived to be more effortful than the 1-finger task (M = 2.11, SD = 1.37), F (1, 46) = 18.03, p < .001, η^2 = .28. The 2-finger task (M = 3.36, SD = 2.12) was rated to be significantly more challenging than the 1-finger task (M = 2.26, SD = 1.44), F (1, 46) = 24.40, p < .001, η^2 = .35. There was no difference between the 2-finger task and the 1-finger task on the fun rating, F <1.

Action initiation. Average response times of the first button press were subjected to a Task difficulty (easy vs. difficult) X Shaping (neutral vs. positive) repeated measures ANOVA. The analyses of the first response latency yielded a main effect of Task difficulty *F*(1, 46) = 5.35, *p* = .025, η^2 = .10; participants were faster in starting the key press in the easy condition (*M* = 253 ms, *SD* = 108) compared to the difficult condition (*M* = 276 ms, *SD* = 126). This indicates that starting behavior was more difficult in response to the presentation of the object when using two fingers compared to one finger to move the object to the front. Both the main effect of Shaping, *F* (1, 46) = 2.68, *p* = .11, and the interaction effect were not significant (*F* <1).

Effort mobilization. The average response latencies of the next 19 button presses per condition were subjected to a Time (2nd to 20th button press) X Task difficulty (easy vs. difficult) X Shaping (neutral vs. positive) repeated measures ANOVA. The analyses of the average response latency of these 19 button presses yielded a main effect of Time, *F* (1, 46) = 29.09, *p* < .001, η^2 = .39, showing that participants generally slowed down during the behavior task. The main effect of Task difficulty was also significant, *F* (1, 46) = 56.01, *p* < .001, η^2 = .60; participants were faster in bringing the object to the front of the hallway in the easy condition (*M* = 168 ms, *SD* = 37) than in the difficult condition (*M* = 186 ms, *SD* = 39). The interaction effect of Time x Task difficulty was not significant, *F* (1, 46) = 2.02, *p* = .16. More important, a significant interaction effect of Task difficulty x Shaping was found, *F* (1, 46) = 5.80, *p* = .020, η^2 = .11 (see Figure 5.6). No other effects were significant, *F*'s < 1.

Tests for simple main effects revealed that object words in the positive difficult condition (*M* = 183 ms, *SD* = 41) were moved faster to the front than object words in the neutral difficult condition (*M* = 190 ms, *SD* = 40), *F* (1, 46) = 4.90, *p* = .032, η^2 = .10. There was no difference between the positive easy condition (*M* = 169 ms, *SD* = 37) and the neutral easy condition (*M* = 167 ms, *SD* = 38), *F* <1.

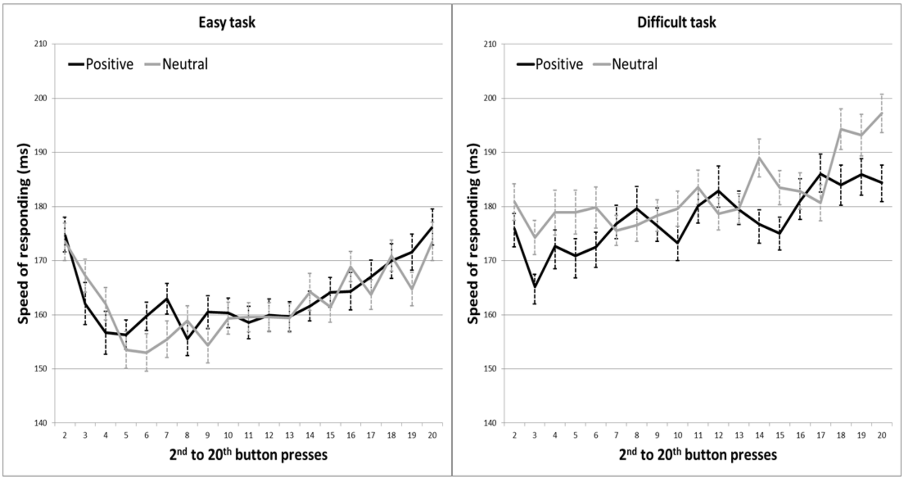

Figure 5.6. Results of Experiment 5.3: Speed of responding (in ms) across the 2nd to 20th button presses as a function of Task difficulty and Shaping.

Discussion

The results of Experiment 5.3 provide further support for the idea that objects induce effortful goal-directed behavior when they are presented as an outcome of action and are accompanied with a positive reward signal. Specifically, apart from that it took participants more time to initiate action when the task was more difficult, it was found that positive shaping of the outcome had a relatively more pronounced effect on speeding up behavior when the behavioral task was difficult compared to when it was easy. This suggests that effort was indeed allocated according to the relative difference between the two levels of difficulty, suggesting that participants distinguished between the different effort requirements and increased motivational intensity accordingly.

This finding is in line with the notion that task difficulty determines the need for effort and that when it is cued beforehand, effort allocation corresponds with the assessed difficulty of the task (Brehm & Self, 1989). Accordingly, in this experiment participants could readily discern the easy from the difficult task, which rendered effort allocation in the easy task worthless; hence we found no effect in the easy condition. In Experiment 5.2 the difficulty of the task was not cued beforehand, and in those cases of unclear task demand effort investment is proportional to potential motivation (Richter & Gendolla, 2006; 2007; 2009; Silvestrini & Gendolla, 2013), so that speeded of responding constituted an absolute measure of effort allocation. This explains why we did find a difference between the neutral and positive condition in Experiment 5.2 and not in Experiment 5.3 for the easy behavioral task.

General discussion

The present research aimed to investigate whether objects that are presented as outcomes of actions are able to induce motivated goal-directed behavior when they are associated with positive signals. The findings of three experiments provided support for this idea. Motivation to obtain specific objects was found to be enhanced when the objects were paired with positive signals, but only when they were presented as outcomes of actions, i.e. when the objects followed rather than preceded an action. Moreover, these effects particularly materialized when behavioral demands were increased, pointing to the motivational quality of the effects in that the interaction between action-outcome information and reward signal processing in producing effortful behavior followed the principle of resource conservation (Brehm & Self, 1989). Interestingly, debriefing reports indicated that, although some participants believed that the positive auditory stimuli might have influenced their responses to the dependent measures, the interactive effects of action-outcome information and positive affect information were not conditional on these conscious self-reports. Our data thus suggest that the motivation to attain desired outcomes or goals may be rooted in an implicit process that combines outcome and positive affective information during action-outcome learning.

Previous research suggests that motivation to attain desired outcomes arises when goals are represented as positive outcomes of actions (Custers & Aarts, 2010). Thus, when a behavioral concept, such as physical exertion or academic achievement, is accompanied with positive affective signals people have been shown to become more strongly motivated to control their behavior accordingly (Aarts et al., 2008; Capa et al., 2011). However, this previous research assumed that the behavioral concepts that are treated with positive signals are subjectively represented as outcomes of actions, but direct evidence for this notion was not established. The present findings manipulated the status of objects in terms of outcomes of actions and demonstrated that such objects gain motivational quality when they serve as action-outcomes and are attached to positive signals. In doing so, the present studies extend previous research by indicating that the co-activation of behavioral concepts and positive reward signals is more likely to motivate goal-directed behavior when the behavioral concept indeed serves as and represents an outcome of action.

The present findings can be considered as a special case of incentive learning (Dickinson & Balleine, 1995), in which the interaction of action-outcome learning (Elsner & Hommel, 2001) and reward signal processing (Bijleveld, Custers, & Aarts, 2012b) seems to follow a self-emergent process that turns action-outcomes attached to positive affect into incentives or desired goals that motivate people to attain them (Marien et al., 2013). However, whereas our findings provide novel insights into the emergence of human motivated goal-directed behavior as a function of the combined role of action-outcome learning and reward signal processing, the process of how this combination produces motivation remains to be elucidated.

For instance, it is not clear why a stimulus that is presented as an outcome of action acquires a different motivational identity when paired with a positive reward signal than a stimulus that is paired with a positive reward signal but is not presented as an outcome. It has been shown that stimuli that co-occur with a positive reward signal usually acquire the valence of the positive signal, and such an evaluative conditioning effect does not seem to be dependent on whether the stimuli are presented as outcomes of actions or not (De Houwer et al., 2001;Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). A follow-up study employing the current action-outcome learning paradigm indeed found an increase in evaluation of objects that are co-activated with positive signals in both the no-outcome and outcome conditions (Marien, Custers, & Aarts, 2014). It could be the case, then, that stimulus and affect information are stored in an additional format when they follow an action. Specifically, it might be adaptive to encode information about rewarding properties of a stimulus in an incentive format when it is an outcome, such that the individual can more easily access and represent it as a desired goal at the time of decision making and performance (Klein-Flügge, Barron, Brodersen, Dolan, & Behrens, 2013; Tachibana & Hikosaka, 2012). Such a learning advantage could be driven by attentional processes that promote the specific encoding of the co-activation of outcome and affect information (Custers & Aarts, 2011). In addition, the affective information might more strongly install a reward signal when it accompanies an outcome than when it accompanies a mere stimulus. Perceiving a stimulus as an outcome may thus change the way in which the accompanying affect is perceived: An implicit signal that producing the effect is rewarding.

Another explanation for the observed effects could be that the learned action-effect relation makes the difference. One could assume that the bidirectional association between the stimulus (in the present study, an object-word) and the action that caused it in the first place generates an internal impulse when the stimulus is encountered again (Hommel, 2013). According to the ideomotor principle, this initial impulse would promote a start-up advantage of behavior to obtain the outcome. Indeed, we only found a facilitation of action initiation in the behavioral task when the object was presented as an outcome of actions. However, when this initiation is not followed by a reward signal (i.e., the established association between outcome and positive affect), the initiated behavior does not persist in the face of effortful demands (Aarts et al., 2008). Transforming stimuli into action-outcome representations thus may provide an initial plan for action, and the positive reward signal constitutes value and thus facilitates effort mobilization and control of behavior to attain the outcome (Nattkemper, Ziessler, & Frensch, 2010).

The ideomotor principle provides a sound account for understanding how action-outcome knowledge is acquired and involved in the selection and control of human action (Brass & Heyes, 2005; Hommel, 2013). However, it is important to note that it does not directly deal with the motivational nature of goal-directed behavior. There is some research investigating the impact of reward signals (i.e., prospective monetary gains) on action-outcome learning, but the analysis mainly focuses on how they affect the binding strength and selection of the associated action itself (Muhle-Karbe & Krebs, 2012). Motivational goal-directed behavior is often conceptualized as being flexible and adaptive and thus is not limited to the execution of well-learned actions associated with the outcomes (Aarts & Elliot, 2012). In the present study, we therefore took a somewhat different approach on the matter by asking participants to perform a different action to obtain outcomes that the one they had learn to associate with the outcome. Yet these non-associated actions were initiated faster and performed with more vigor, suggesting that the positively shaped outcomes operated as a desired goal in organizing some level of behavioral flexibility as a result of incentive learning (Balleine, 2011).

This is in line with the notion that reward signal processing is closely linked with adaptive and flexible control of human action (Chiew & Braver, 2011). Whereas outcome representations serve as reference points for perception and action (Carver & Scheier, 1982; Powers, 1973), accompanying positive reward signals assign value or utility to outcomes (Shizgal, 1999) and facilitate the recruitment of executive control processes (Locke & Braver, 2010). For instance, in a study using a task-switch paradigm (Marien et al., 2012), it was found that encouraging participants to represent their behavior in terms of the outcome of the task rendered performance more flexible (easier switch from one task-set to another), but this adaptive control mainly occurred when the outcome representation was accompanied by positive reward signals.

In general, our findings concur with the idea that human adaptive action control is an emergent property of the dynamic interactions of multiple brain systems (Miller & Cohen, 2001; Miyake & Shah, 1999). For example, the cognitive control model of Cohen and colleagues includes three specialized brain systems (prefrontal cortex, hippocampus and a posterior perceptual and motor cortex) that contribute to working memory functions and goal-directed thought and action. However, the cortical processing in these systems are modulated by the mesolimbic dopamine system – a brain system that is associated with affective-motivational processes. The present research may offer a learning perspective on this matter that considers the motivation and resultant operation of goals to emerge from interactions of information about action-outcome concepts and positive affect.

Investigating human adaptive action control in terms of an emergent property of the mind can also lead to interesting perspectives on issues of behavioral regulation and change. For example, recent research suggests that executive functions play a central role in effective self-regulation, and issues with self-regulation are tackled by taken an individual difference perspective on the main mental components of executive functions, such as differences in working memory capacity (Hofmann, Schmeichel, & Baddeley, 2012). Although these differences in capacity are important, people are likely to use their ability for self-regulation only when it is worth the effort. The findings of the present paper suggest that people can become motivated to spend more effort by reward signals that accompany outcomes. Action-outcome learning might thus be a promising tool to encourage people to put more effort into attaining outcomes instead of direct rewards resulting from their actions (e.g., spending money now instead of saving it for later).

A large part of the goals that people pursue may be acquired through experience with action-outcome contingencies that were accompanied with positive reward signals. This process can possibly lead to the adoption of strong but unhealthy motivations such as in the use of addictive substances (Köpetz, Lejuez, Wiers, & Kruglanski, 2013). If there is indeed reason to believe that a basic learning mechanism explains unhealthy motivation, another strategy to tackle self-regulation issues might be to help people acquire healthy action-outcome relationships in reward learning contexts. A similar approach might also be fruitful in the context of societal issues of collective well-being, such as motivating people to contribute to the public good (Fehr & Gächter, 2000; Raub & Buskens, 2008).

To conclude, in the present research we explored the potential building blocks of motivated goal-directed behavior by examining how action-outcome learning interacts with positive affective signals in motivating people to obtain outcomes. Our findings suggest that that people's motivation can be shaped by positive reward signals, but that this particularly might induce idiosyncratic goal-directed motivation when the person (albeit implicitly or explicitly) learns to produce the desired outcome herself.

APPENDIX

Mean Valence and Standard deviation of Object and affective words (translated from Dutch)

Object words in alphabetical order	Mean Valence	SD
AGENDA	5.57	2.53
BALLPOINT PEN	6.23	1.91
BANJO	6.73	1.41
CELLO	6.83	1.76
CLARINET	4.03	1.90
COMPASSES	5.10	2.14
DRUM	5.90	1.73
ERASER	5.10	1.84
FLUTE	6.27	1.64
HORN	4.73	1.91
MARKER	5.43	1.89
PENCIL	5.97	1.87
RULER	5.37	1.59
SAXOPHONE	6.93	1.64
SCISSORS	5.27	1.80
SCOTCH TAPE	5.10	1.84
SHARPENER	5.37	1.97
TRIANGLE	6.03	1.94
TROMBONE	5.86	1.92
TUBA	5.73	1.36
Affective words in alphabetical order	**Mean Valence**	**SD**
BEAUTIFUL	8.03	1.15
FINE	7.69	1.47
GOOD	7.86	1.14
HANDSOME	7.80	1.28
NICE	7.57	1.20
NOW	4.86	1.85
SOMETIMES	4.40	1.03
THERE	5.26	0.70
WITH	4.49	1.50
YET	4.20	1.13

Mean scores on a 9-point scale: higher scores imply more positivity

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Samenvatting

Mensen voeren dagelijks een heleboel taken uit die behoorlijk wat moeite kunnen kosten. Het is bijvoorbeeld niet altijd even makkelijk om iedere dag met de fiets naar het werk gaan, zeker niet wanneer het toevallig heel hard regent. Op dat soort momenten kost het uitvoeren van de taak (naar het werk gaan met de fiets) extra veel moeite. Niet alleen moet de verleiding weerstaan worden om toch maar weer de auto te nemen, ook moeten er andere acties geïnitieerd worden, zoals bijvoorbeeld het aantrekken van een regenpak, om de taak naar behoren uit te kunnen voeren. Gelukkig zijn mensen uitgerust met een aantal controlefuncties die het overwinnen van deze obstakels mogelijk maken zodat het gewenste resultaat toch behaald kan worden.

Dit soort doelgericht gedrag gaat vaak gepaard met controle processen. Echter, het vergt veel inspanning om controle processen aan te wenden, dus het is wel van belang dat het de moeite waard is om deze inspanning te leveren voor de gewenste uitkomst. Hiervoor heeft een mens de informatie nodig dat een uitkomst inderdaad bereikt kan worden met bepaalde acties en de informatie dat deze uitkomst waardevol is, of met andere woorden belonend is. Dan pas zullen mensen gemotiveerd worden om doelgericht gedrag te vertonen en controle processen in te zetten. In dit proefschrift werd onderzocht hoe deze eenvoudige bronnen van informatie op elkaar inwerken om het onderliggende mechanisme van doelgericht gedrag beter te begrijpen.

Om dit te kunnen onderzoeken vertrekt dit proefschrift vanuit de aanname dat doelgericht gedrag bestaat uit twee basale kenmerken. Aan de ene kant zijn doelgerichte acties initieel aangeleerd door vaak te ondervinden wat de uitkomst is van een actie. Bijvoorbeeld, iemand kan leren welke knop er ingedrukt moet worden om het licht aan te doen door simpelweg te ondervinden dat de lamp aanging (uitkomst) nadat er op de knop werd gedrukt (actie). Als op een later moment deze persoon dan bedenkt dat het licht aangedaan moet worden, kan de juiste actie meteen geselecteerd worden. Aan de andere kant ontstaat gemotiveerd doelgericht gedrag vanuit de belonende waarde van de uitkomst. Deze belonende waarde kan verwijzen naar een doel op zich, zoals bijvoorbeeld het verdienen van geld, maar kan ook verwijzen naar informatie die op het moment van het bereiken van de uitkomst aanwezig is in de omgeving, zoals bijvoorbeeld een vriendelijke opmerking van een ander persoon of een plaatje dat een positief gevoel opwekt. Zo zal bijvoorbeeld iemand die geleerd heeft dat het licht aandoen een aangenaam effect heeft meer moeite gaan doen om deze uitkomst te bereiken. Met andere woorden, uitkomsten die gekoppeld zijn aan beloningssignalen zullen er toe leiden dat een persoon meer inspanning zal leveren en controle processen zal aanwenden om gedrag te sturen.

In hoofdstuk 2 van dit proefschrift werd een theoretisch perspectief geboden over hoe informatie over de uitkomst van een actie en informatie over de belonende waarde op elkaar inwerken om doelgerichte controle processen aan te wenden. Er werd geopperd dat beloningssignalen die de actie-uitkomst informatie vergezellen de waarde aanduiden van deze uitkomst. Hierdoor wordt het aanwenden van controle processen de moeite waard en zal het bereiken van de uitkomst ondersteund worden door controlefuncties die ervoor zorgen dat gedrag volhardend is, maar er ook voor zorgen dat gedrag wordt aangepast wanneer de situatie daar om vraagt.

Gebaseerd op deze theoretische analyse worden in de daaropvolgende drie empirische hoofdstukken drie aspecten getest die veel inzicht kunnen geven in het onderliggende mechanisme van doelgericht gedrag. Meer bepaald, in hoofdstuk 3 werd onderzocht hoe beloningsinformatie de hoeveelheid inspanning bepaalt door in te werken op de vraag naar controle. Uit de psychologische literatuur is bekend dat het leveren van inspanning bepaalt wordt door een afweging tussen de moeilijkheid van de taak en de beloning die daar tegenover staat. Met andere woorden mensen gaan pas een inspanning leveren wanneer het echt de moeite waard is. Wanneer de taak makkelijk is of geen waarde heeft zal men die inspanning juist niet leveren om energie te kunnen besparen. In hoofdstuk 3 werd onderzocht of deze afweging ook gemaakt wordt wanneer deze informatie over de moeilijkheid van de taak (ofwel de vraag naar controle) niet van te voren bekend is. Er werd inderdaad gevonden dat beloningsinformatie alleen tot meer inspanning leidde precies op het moment dat er ook daadwerkelijk controle benodigd was. Dit effect suggereert dus dat controle voor doelgericht gedrag het resultaat is van een simpele wisselwerking tussen informatie over de vraag voor controle en informatie over de beloning, en dat dit gebeurt zonder van te voren te bepalen of het leveren van een inspanning de moeite waard is. Doelgerichte controle kan dus als het ware uit zichzelf ontstaan.

In hoofdstuk 4 werd het leveren van een inspanning op een andere manier benaderd. Hier werd het controle proces onderzocht dat er voor zorgt dat mensen over kunnen schakelen naar een andere actie wanneer dat vereist is. Dit soort aanpassingen in gedrag kosten ook moeite en naarmate er meer inspanning wordt geleverd kunnen mensen deze overschakeling sneller uitvoeren. Dit zou dus ook betekenen dat beloningssignalen de snelheid waarmee mensen hun acties aanpassen kunnen beïnvloeden wanneer deze beloningen gekoppeld zijn aan de uitkomst van de actie. Met behulp van een zogenaamd *task switch* paradigma werd gedemonstreerd dat mensen sneller in staat waren om te wisselen van actie om een uitkomst te bereiken wanneer deze uitkomst gekoppeld was aan positieve beloningssignalen. Deze wisselwerking tussen beloning en uitkomst maakt mensen dus ook flexibeler in hun doelgericht gedrag. Echter, er werd ook gevonden dat mensen meer rigide werden (dus minder snel overschakelden) wanneer de beloning gekoppeld was aan de actie zelf en niet aan de uitkomst. Dit suggereert dat de manier waarop beloningssignalen doelgericht gedrag motiveren afhankelijk is van hoe gedrag mentaal gerepresenteerd wordt, namelijk in termen van de uitkomst of in termen van de actie zelf. Wederom is dit een demonstratie dat doelgericht gedrag uit zichzelf kan ontstaan en zijn eigen richting bepaalt op basis van een eenvoudige wisselwerking tussen informatie over de actie, de uitkomst en de beloning.

In hoofdstuk 5, ten slotte, werd onderzocht of het ontstaan van gemotiveerd doelgericht gedrag zich ook voor doet in een context waarbij de actie en de uitkomst nog gekoppeld moeten worden. Hiervoor werd een paradigma ontwikkeld waarin het leerproces gesimuleerd werd waarin mensen eerst moeten ondervinden wat de uitkomst is van hun actie, voordat ze de uitkomst kunnen nastreven. Door dit leerproces te combineren met beloningsinformatie of niet, kon getest worden of het ontstaan van gemotiveerd doelgericht door beloningssignalen afhankelijk is van het leermechanisme van actie-uitkomst associaties. Er werd gevonden dat na deze leer fase mensen inderdaad alleen meer inspanning leverden in een doelgerichte taak wanneer de beloningssignalen gekoppeld waren aan de uitkomsten van acties die net geleerd waren. Mensen werden niet expliciet gevraagd om inspanning te leveren in deze taak dus ook hier ontstond het doelgericht gedrag uit zichzelf.

Samenvattend, het onderzoek in dit proefschrift laat zien dat gemotiveerd doelgericht gedrag kan ontstaan uit een patroon van relatief eenvoudige interacties tussen informatie over uitkomsten en beloningen. Dit biedt een ander perspectief op het begrijpen van doelgericht gedrag en kan hopelijk bijdragen aan de ontwikkeling van nieuwe inzichten in het onderzoek naar menselijke controle en motivatie in het algemeen.

Dankwoord

Om een proefschrift af te ronden heeft een mens heel veel motivatie nodig. Deze motivatie komt, zoals in dit proefschrift is beschreven, vooral voort uit een interactie tussen informatie die te maken heeft met de uitkomst van een actie en informatie over de beloning die daar aan vast hangt. Een heleboel mensen in mijn omgeving hebben ervoor gezorgd dat deze informatie bij mij op de juiste manier is verwerkt, want anders zou u dit proefschrift nu niet in uw handen hebben.

De eerste persoon die deze informatie op onvermoeibare wijze verstrekt heeft, en blijft verstrekken, is Henk. Iedere meeting, telkens met evenveel passie, maakte je me op een of andere manier duidelijk waar ik dit allemaal voor deed en hoe ik dit allemaal moest doen. Het is bijna onmogelijk om te bevatten hoeveel ik van je geleerd heb. Ik kan me geen betere promotor voorstellen! Mijn dank is enorm groot en ik hoop nog vaak met je te kunnen samenwerken in de toekomst.

Dan is er Ruud. Het is een groot voorrecht dat jij mijn co-promotor bent. Ik heb ontzettend veel van je geleerd en heb steeds met veel plezier met je samengewerkt aan dit project! Op meesterlijke wijze hanteerde jij de combinatie van beloningssignaal en uitkomst. “Het ziet er goed uit, maar…”. De kwaliteit van dit proefschrift heeft er niet onder geleden kan ik je vertellen, en dat waardeer ik enorm!

Erik, jij bent een inspiratiebron geweest vanaf het begin. Ik ken weinig andere mensen die met zoveel overgave er iets van proberen te maken. In je werk laat je steeds zien wat allemaal óók nog kan en niet alleen maar dat wat er minimaal nodig is. Dat is inspirerend en wordt nu al gemist op de afdeling. Ook op sociaal gebied loop je de kantjes er niet van af, en ik hoop dat ik daar ook nog lang mee mag van genieten!

Graag wil ik ook alle collega’s van de afdeling Sociale en Organisatiepsychologie bedanken. Jullie hebben allemaal in meer of mindere mate bijgedragen aan de totstandkoming van dit proefschrift. Waarvoor dank! Ik kwam iedere dag weer met alle plezier naar de afdeling en dat heeft alles te maken met de uitzonderlijke collegiale sfeer. Zonder uitzondering stond iedereen altijd klaar om even te hulp schieten. Ik ben blij dat ik zelf deel heb kunnen uitmaken van dit collectief!

Tot slot, Susanne, ondanks het feit dat je af en toe van jezelf zegt dat je ongeduldig van aard bent, ben jij degene die het meeste geduld heeft opgebracht. Er is behoorlijk veel quality time van ons opgeofferd voor dit hele project. Dat hoort er soms ook bij, maar is zeker niet vanzelfsprekend! Ik ben je daar heel erg dankbaar voor. Zonder deze onvoorwaardelijke steun was het allemaal niet gelukt. Ik hou van je!

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