Exp Brain Res (2013) 229:475–484
DOI 10.1007/s00221-012-3370-7

VOLITION

Motivation from control

Baruch Eitam · Patrick M. Kennedy · E. Tory Higgins

Received: 10 September 2012 / Accepted: 5 December 2012 / Published online: 4 January 2013

Abstract Human motivation is sensitive to value—to the outcomes of actions. People invest mental and physical resources for obtaining desired results or for stopping and reversing undesired ones. Accordingly, people's motivation is sensitive to information about their standing in relation to outcome attainment ('outcome feedback'). In this paper, we argue and present the first evidence for the existence of another motivational sensitivity in humans—a sensitivity to our degree of control on the environment and hence to information about that control ('control feedback'). We show that when actions have even trivial and constant perceptual effects, participants' motivation to perform is enhanced. We then show that increased motivation is not because more information about task performance is available and that motivation is increased only in conditions in which control over the effects can be firmly established by the mind. We speculate on the implications for understanding motivation, and potentially, physical and mental health.

Keywords Motivation · Agency · Reward

Introduction

Knowing what effect one's action has had on the environment (henceforth, effect) is integral to the mechanics of human motivated behavior. In past and current ideomotor-based theories of action control, effects play a central role in the selection of goal-directed actions (Hommel et al. 2001; James 1890; Prinz 1997; for recent reviews, see Hommel 2009; Shin et al. 2010). Effects are, of course, crucial information for knowing whether a purposive, goal-directed action was successful in obtaining a desired outcome (Carver and Scheier 1990; Lewin 1935; Miller 1960). Thus, in current theories of human action, effects provide information about how we are doing (or what we should do) in relation to obtaining desired outcomes.

In other words, such theories emphasize the information that effects carry about *valued* outcomes. We term this role of effects, 'outcome feedback'. When functioning as outcome feedback, action effects motivate by providing information about our standing in relation to a desired outcome.

In this paper, we build on previous work in the psychological literature to suggest that *effects* carry another type of information as well—that the organism has control over the environment. We call this type of information, 'control feedback'. We hypothesize that the exercise of control is itself motivating above and beyond the information it carries as outcome feedback. To differentiate control effects from valued effects, we term this hypothesis, Control Effect Motivation (CEM).

Motivation from control effects

The idea that human motivation is sensitive to one's control over what happens is not new (White 1959; for a recent review, see Higgins 2012). White (1959), for example, posited that what he called 'effectance' is itself another drive or motivator. Other theories of human motivation also recognized the role of control in motivation, such as expectancy-value theory (Atkinson 1957), learned helplessness theory

B. Eitam (✉)
Psychology Department, University of Haifa,
7080 Rabin Complex, 31905 Mount Carmel, Haifa, Israel
e-mail: beitam@psy.haifa.ac.il

P. M. Kennedy · E. Tory Higgins
Psychology Department, Columbia University,
New York, NY, USA

(Seligman 1968), or self-efficacy theory (Bandura 1977). But, notably, they did not propose that one's control *itself* motivates.[1] Rather, in these theories, perceived control functions as a modulator of what we have termed above outcome feedback: either by modulating outcome value itself (Atkinson 1957), the expectancy of escaping an undesired outcome (Abramson et al. 1978; Seligman 1968), or by affecting one's consciously perceived ability to perform a goal-directed behavior (Ajzen 1991; Bandura 1977).

But if 'effectance' is itself a motivator as White (1959) has argued, effects as feedback about one's control should be directly motivating. Furthermore, control feedback should motivate over and above the outcome feedback this information also carries because each kind of feedback 'speaks to' a different way of being effective (i.e., being effective in having desired outcomes vs. being effective in managing to make something happen in the environment; see Higgins 2012).

Indeed, in other species, there is some evidence that effects as feedback about one's potential or actual control also affect motivation. For example, Harlow and colleagues demonstrated that monkeys repeatedly manipulate both mechanical and non-mechanical objects without being otherwise reinforced (Harlow et al. 1950). Similarly, Moon and Lodahl (1956) showed that both an increase and decrease in illumination contingent on a lever press led monkeys to increase the frequency of pressing that lever, and Barnes and Kish (1961) demonstrated that auditory stimulation contingent on a lever press has a similar motivating effect.

Empirically establishing that a control effect motivates humans will further challenge the still dominant position that action and cognition are motivated solely by the search for desired outcomes (Eitam and Higgins 2010; Higgins 1997, 2012; see also Bromberg-Martin and Hikosaka 2009).

Testing the control effect motivation (CEM) hypothesis

We propose that humans are motivated by control effects. In this study, we test one form of control effect—an action having a trivial perceptual influence on the environment. Specifically, in three experiments, we show that humans will be more motivated when their action has a perceivable effect (Experiment 1). If actions do not have such a perceivable effect, *regardless of whether the mind knows it is standing in relation to a current goal*, the actor, deprived of such control feedback, will be less motivated (Experiment 2). Thus, CEM hypothesis breaks from earlier theorizing on the role of effects in human action by arguing that control effects are motivating only when they are clear feedback about one's control (Experiment 2 and 3).

General method

In all three experiments, we used a task we developed. In this task, participants respond to colored circles that appear, one by one, at the top of the screen and rapidly descend in a vertical line to the bottom. Participants' instructions (see Fig. 1) are to 'stamp' the circles as they appear on the screen by pressing one of the four keys on a regular keyboard ('s', 'd', 'h', and 'j'). A fixed time interval had passed from the appearance of the previous trial, regardless of the participants' response speed in the former trial.

In all experiments, participants completed 3 blocks of 60–120 trials each. There was no indication that a block had ended. In all studies, our central dependent variable was response time, with correct responses (which were generally high) measured to verify that there were no speed-accuracy trade-offs.

Experiment 1: Having an effect enhances performance

Materials and methods

Participants

Seventy-two undergraduate students (41 females, mean age = 22.01, SD = 5.05) participated in the experiment in exchange for course credit or pay. Participants were run individually and were randomly assigned to one of the two conditions.

Fig. 1 Stamp instructions screen. To emphasize both speed and accuracy in Experiments 2 and 3, after the participant had finished reading the instructions, the experimenter add, 'We will be recoding the speed and accuracy of your responses'

1 As noted above, the idea that perception of an effect facilitates the selection (i.e., activation) of an action that is associated with it (i.e., learned) is central to modern versions of the ideomotor principle. What we are proposing is that the mere categorization of a perceptual event as an effect, regardless of its specificity, reinforces the action that has produced it. We elaborate on this issue further in the "General discussion" section.

Materials

We used the task described above with the following parameters: circles moved down the game window at the rate of approximately .46 pixels per ms, such that the game window was roughly 850 ms long. The vertical distance between circles was fixed as the height of the game window plus the height of the circle. This meant that the ISI was kept constant throughout the task, roughly 880 ms.

Design

We manipulated one between-participants factor—*Effect*. Did the rapidly descending circles flash and disappear when participants pressed the correct key? Yes they disappeared (Effect condition); No they did not disappear (No Effect condition). A second, within-participants factor was *Block*. The sole difference between the two conditions was that in the Effect condition when participants pressed the correct key—corresponding to the horizontal location of the descending circle—the circle briefly flashed and disappeared. In the No Effect condition, the circle continued falling and no perceptual indication that the participant's response had an effect was given. Note that for all participants, the next trial would begin (i.e., the next circle appeared) only after the full time it took a circle to descend from top to bottom had passed.

Results

Performance

In this and all the following experiments, we applied the following filters before analyzing the data. First, the data from 6 participants that did not adhere to experimental instructions (i.e., performed below an average of 50 % correct responses) were removed from further analysis. To validate the use of our main dependant variable, all incorrect responses were dropped for all RT analyses (2,819 of 23,760 trials, i.e., less than 12 % incorrect). Then, the data from another participant who deviated from their condition's mean by 2 standard deviations in either mean response times or percent correct responses were not analyzed further.

For assessing participants' performance on the stamp task, mean response times and percent of correct responses were averaged over block and a mixed ANOVA was performed separately on each performance measure. For response times, a two-way mixed ANOVA with *Block* (1 vs. 2 vs. 3) as a within-participants factor and *Effect* (No Effect vs. Effect) as a between-participants factor.[2] The ANOVA revealed a reliable effect of having an effect $F(1, 63) = 5.08$, $p < .05$. Participants in the Effect condition responded faster overall than the participants in the No Effect condition (see Fig. 1; Tables 1, 2). *t* tests performed on the difference between the individual cell means showed that participants in the Effect condition were reliably faster than those in the No Effect condition on the last, and second-to-last, blocks (see Tables 1, 2).[3]

The comparable ANOVA on the percent of correct responses did not reveal a difference between the Effect and No Effect conditions, $F < 2$, countering a speed-accuracy trade-off explanation.

To summarize the results of Experiment 1, having an effect had a clear positive effect on performance. Participants whose actions were experimentally manipulated to have a perceivable effect performed the task better (i.e., faster) than participants whose actions did not have such an effect.

While Experiment 1 provides support for CEM, alternative explanations for our findings exist. In the next experiments, we tested the most prominent alternative to our CEM hypothesis. Specifically, might the results of Experiment 1 be explained by differences in outcome feedback (vs. control feedback as we have argued)? First, participants in the Effect condition could have clearer/more salient outcome feedback, and clearer outcome feedback produces more certainty about their responses. This certainty about, for example, their key press having being registered or that a specific trial had ended could benefit their performance by freeing resources for preparing for the next trial. Second, the perceptual effect could provide information about goal attainment or success, which could benefit performance by motivating participants because it signals that they are doing well (e.g., Carver and Scheier 1990).

To test this alternative (outcome feedback) account, in Experiment 2, we equated the outcome feedback for participants in the Effect and No Effect conditions, while maintaining the difference between these conditions regarding control feedback. We did this by giving participants in both the Effect and the No Effect groups trial-by-trial outcome feedback about their performance. This information was conveyed as a running score that provided complete information about their success outcomes. If there were still higher performances in the Effect group than the No Effect group under these conditions, then the alternative outcome feedback account would not be supported.

[2] The (beneficial) effect that Block had on performance was reliable in all studies. Due to its irrelevance to our hypothesis and severe space constraints it will not be further mentioned.

[3] Each cell was compared to the corresponding cell in the other condition.

Table 1 Mean response times: no effect condition

Experiment	Block			
	1	2	3	Overall
Exp. 1 ($n = 31$)	477.57 (74.77)	462.83 (69.24)	476.6 (83)	472.33 (71.66)
Exp. 2 ($n = 17$)	464.84 (98.03)	454.68 (70.65)	463.02 (66.72)	460.84 (69.53)

Values in parentheses are standard deviations

Table 2 Mean response times: effect condition

Experiment	Block			
	1	2	3	Overall
Exp. 1 ($n = 34$)	450.71 (61.24)	428* (52.66)	434.05* (47.5)	437.59* (52.82)
Exp. 2[a] ($n = 18$)	412.59^ (51.1)	388.75** (43.27)	379.62** (45.22)	393.65** (40.83)

Values in parentheses are standard deviations

^ $p \leq .05$ (one-tailed); * <.05; ** <.01; [a] modified condition

Experiment 2: Matching outcome feedback

Materials and methods

Participants

Forty-two undergraduate students (18 females, mean age = 22.83 years, SD = 7.2) participated in the experiment in exchange for course credit or pay. Participants were run individually and were randomly assigned to one of the two conditions.

Materials

We used the task with the following parameters. To give all participants full outcome feedback, we added a running score counter at the top center of the screen. Each correct response led to an increase of one point by the counter. The task instructions told the participants that there was a score counter that would provide feedback about their performance. The counter was placed in a position that enabled participants to attend it and then choose the next correct response. If outcome feedback was to explain the results, attending only to the score should lead to a response-time advantage over attending only to an effect (and even more to attending to both) because it would both supply full outcome feedback while preparing the participants to readily 'ambush' the circles at their 'source' (i.e., the top of the screen). All other parameters were kept identical to those used in Experiment 1.

Design

The design was identical to that of Experiment 1. The sole difference being that in both conditions, a running score appeared in the top center of the screen.

Results

Performance

As in all experiments, we applied the following filters before analyzing the data. The data of 4 participants that did not comply with the experimental instructions were removed from further analysis. For response-time analyses, all incorrect responses were dropped (2,187/14,040; less than 16 %). Then, the data from 3 participants that deviated from their condition's mean by 2 standard deviations in either mean response time or percent correct responses were not further analyzed.

Analyses were identical to those conducted for Experiment 1. A two-way mixed ANOVA with Effect (No Effect vs. Effect) as a between-participants yielded a reliable main effect of having an effect $F(1, 33) = 11.51$, $p < .01$. Replicating Experiment 1, participants in the Effect condition responded faster than those in the No Effect condition (see Fig. 2; Tables 1, 2). t tests performed on the relevant cell means revealed that participants in the Effect condition were reliably faster on all three blocks (see Tables 1, 2). The comparable ANOVA on the percent of correct responses ruled out a speed-accuracy trade-off (see Tables 3, 4).

Thus, having an effect again enhanced performance on the task. Crucially, this occurred even when participants in the No Effect condition were given full outcome feedback in the form of a running score. In this experiment, the performance benefit from having an effect must have been driven by the difference in control feedback.

The results of Experiment 2 do not support the outcome feedback alternative to CEM. They do support the proposal that control feedback can enhance motivation over and above outcome feedback. Experiment 3 was designed to directly test the link between control feedback and the increased motivation observed in Experiments 1 and 2. It capitalized on recent work demonstrating that the mind

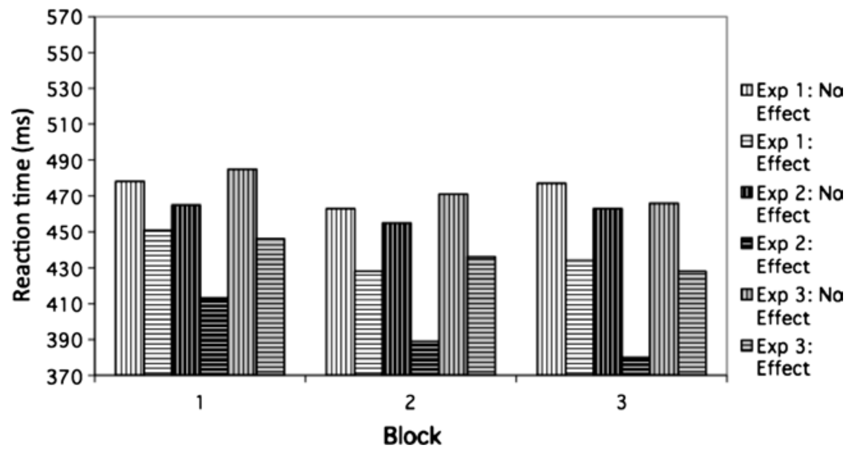

Fig. 2 Mean response times by Block for Immediate Effect and No Effect conditions in all experiments. The Immediate Effect conditions are *horizontally patterned* and the No Effect conditions are *vertically patterned*. *Shade* denotes Experiment. All main effects of condition are reliable (two-tailed; see text)

Table 3 Mean percent correct no effect condition

Experiment	Block			
	1	2	3	Overall
Exp. 1 ($n = 31$)	86 % (8)	90 % (11)	86 % (17)	87 % (9)
Exp. 2[a] ($n = 17$)	79 % (16)	89 % (11)	87 % (7)	85 % (10)

Values in parentheses are standard deviations

[a] modified condition

Table 4 Mean percent correct effect condition

Experiment	Block			
	1	2	3	Overall
Exp. 1 ($n = 34$)	87 % (9)	92 % (5)	91 % (7)	90 % (5)
Exp. 2[a] ($n = 18$)	84 % (17)	89 % (6)	87 % (9)	87 % (8)

Values in parentheses are standard deviations

[a] modified condition

is sensitive to subtle time lags between actions and their effects (as short as 300 ms) even when people are not aware that there was a lag (see David et al. 2008). We reasoned that inserting such a brief lag between an action and an effect degrades the quality of control feedback (David et al. 2008); if this would decrease, or even eliminate, the performance advantage in the Effect (vs. No Effect) condition, then this would be strong evidence toward control feedback being the source of the motivation benefit. This is because a subtle lag should not similarly affect outcome feedback in any way because the mind still has full (albeit lagged) information that the goal of 'stamping' the circle was successfully completed before the end of the trial. Thus, if control feedback is a distinct source of motivation over and above outcome feedback, then lowering the quality of control feedback while maintaining that of the outcome feedback should reduce or even eliminate the performance benefit from having an effect.

Experiment 3: Introducing uncertainty about self-authorship

Materials and methods

Participants

Eighty-two undergraduate students (46 females, mean age = 22.27 years, SD = 6.9) participated in the experiment in exchange for course credit or pay.[4] Participants were run individually and were randomly assigned to one of the four conditions: No Effect, Immediate Effect, a Short Lag Effect condition in which an effect (the flash and disappearance of the circle) occurred 300 ms after a correct response, and a Long Lag Effect condition in which an effect occurred 600 ms after a correct response.

Materials

We used the stamp task with the following parameters. The game window was increased from 385 pixels to 601 pixels to allow time for the lagged effect to appear. This increased the game window from approximately 850 ms to approximately 1,300 ms.[5] The ISI was therefore increased from approximately 1,000 ms to approximately 1,450 ms. All other parameters were kept identical to the two previous experiments.

[4] Three participants did not report their gender.

[5] Based on adding 2 standard deviations from the maximal mean RT from all other experiments. This was intended to ensure that about 95 % of the effects in the long lag condition would actually show up on the screen.

Design

Apart from the addition of the two lag conditions, the design was identical to that used in the two former experiments.

Results

Performance

We applied the same filters as in the former experiments. First, the data of 4 participants that did not comply with the experimental instructions were removed from further analysis. For response-time analyses, all incorrect responses and ones that were preceded by a false alarm were dropped (3,726/29,160 = 13 %). For percent correct analyses, responses that were preceded by a false alarm were dropped (2,270/29,160 = 8 %). Then, the data from 7 participants (~9 %) that deviated from their group's mean by 2 standard deviations in either mean response time or percent of correct responses were not included in further analyses.

Results were analyzed as in the two previous experiments. Trials were averaged over each block (now 60 trials long each) and subjected to a mixed ANOVA performed separately for response times and percent of correct responses.

For response times, a two-way mixed ANOVA with *Effect* (No Effect vs. Immediate Effect vs. Short Lag Effect vs. Long Lag Effect) as a between-participants factor yielded a reliable main effect of having an effect (see Fig. 3), $F(3, 67) = 2.85$, $p < .05$. *t* tests performed on the relevant means revealed the following findings: First, replicating Experiments 1 and 2, participants in the Immediate Effect condition were faster than those in the No Effect condition. Second, participants in the Short and Long Lag Effect conditions were *not* reliably faster than participants in the No Effect condition. Thus, the performance benefit from having an effect was eliminated even when there was only a brief 300 ms lag (see Tables 5, 6).[6]

The comparable ANOVA on the percent of correct responses did not reveal a reliable effect of Effect condition, again ruling out a speed-accuracy trade-off (see Table 6).

In sum, the performance results of Experiment 3, beyond providing a second replication of the motivating influence of an immediate effect, supply evidence that this motivation relates to mechanisms of judgment of authorship over managing an effect (i.e., control). Furthermore, as all Effect conditions received complete outcome feedback before the trial had ended and the next trial began, this study weakens alternative explanations focusing on uncertainty or efficacy, as it is not clear how these could have influenced the next trial given the same outcome feedback.

To summarize, the results of Experiment 3 show that the motivational consequence of having an effect is tightly time locked to a commission of a response. The decrease in the performance benefit of having an effect is already apparent when a perceptual event (i.e., an effect) appears only 300 ms after a response. As outcome information was equally available and salient in all Effect conditions, it is the difference between them in their function as control feedback that matters for motivation. Introduction of a brief lag decreases the mind's certainty that it was its action that controlled the effect.

General discussion

Three experiments demonstrate that having an effect enhances performance. This pattern of findings cannot be explained by current versions of ideomotor theories because they stress the mechanism of a specific effect activating the specific response that is associated with it (e.g., Hommel et al. 2001). These theories are also silent on why introducing a brief time lag would eliminate response facilitation (Experiment 3).[7] Furthermore, although consistent performance differences could be driven by factors other than control feedback, we have ruled out the most prominent alternative. Having an effect did not influence performance through functioning as outcome feedback—specifically, by providing clear feedback that a trial has ended or feedback about being successful in goal attainment (Experiments 2 and 3).

We conclude that the pattern of findings supports the hypothesis that having an effect is motivating. Motivation came from the fact that the event is registered as an effect of one's actions, which is control feedback. Note that this registration does not necessarily depend on a conscious judgment of contingency between action and effects (e.g., Moore et al. 2012) or on an explicit feeling of control (Eitam and Higgins 2010).

Before moving on to elaborate on what we think these findings mean, one limitation of the current study should be explicitly acknowledged. While we argue that effects are motivating regardless of the value (and hence, task relevance) of an effect, in the current experiments, the effect

[6] The marginal reliability of the effect of effect on RT's led us to replicate this study. We obtained a reliable result. The data from this study will be made available on request.

[7] Other work has demonstrated that introducing a longer time lag (1–2 s) decreases both people's action-effect contingency judgments and motivation to act (e.g., Shanks and Dickinson 1991). We have evidence for dissociation between people's feeling of effectiveness (as a proxy for contingency judgments) and performance facilitation (Eitam and Higgins 2012). Specifically, in the 300 ms lag condition participants' judgments of effectiveness are no different than in the immediate lag condition but the facilitation of action, as in the current case, disappears.

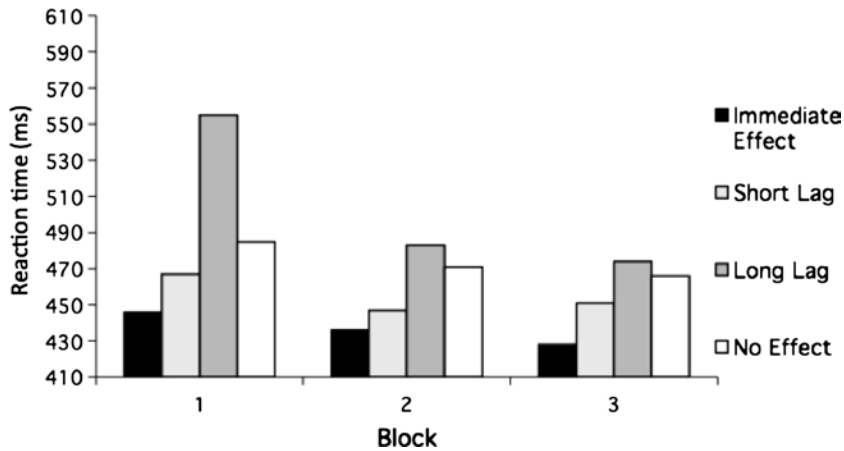

Fig. 3 Experiment 3. Mean response times by Block for Immediate, Short Lag (300 ms), Long Lag (600 ms), and No Effect conditions in Experiment 3. Planned contrasts show that while the Immediate Effect condition is reliably faster from the No Effect condition F (1, 209) = 8.07, p = .01, the Short F (1, 209) = 1.95, p = .16 and Long Lag conditions F (1, 209) = 4.53, p = .04, are not. In fact, in this experiment, the Long Lag condition was reliably *slower* than the No Effect condition, but as this difference did not replicate in an additional study, we do not discuss it further

Table 5 Experiment 3—mean response times

Condition	Block			
	1	2	3	Overall
Immediate effect (n = 21)	446 (63)	436 (65)	428 (62)	437* (58)
Short lag (n = 18)	467 (91)	447 (71)	451 (70)	455 (73)
Long lag (n = 15)	555 (159)	483 (71)	474 (44)	504 (67)
No effect (n = 17)	485 (90)	471 (88)	466 (91)	474 (84)

Comparisons are to no effect condition. Values in parentheses are standard deviations

* <.05

Table 6 Experiment 3—mean percent correct

Condition	Block			
	1	2	3	Overall
Immediate effect (n = 21)	91 % (8)	91 % (7)	89 % (7)	91 % (7)
Short lag (n = 18)	95 %^ (5)	94 % (4)	92 % (7)	94 % (5)
Long lag (n = 15)	94 % (8)	95 % (4)	94 % (7)	94 % (4)
No effect (n = 17)	94 % (5)	92 % (7)	90 % (10)	92 % (7)

Comparisons are to no effect condition. Values in parentheses are standard deviations

^ p ≤ .05 (one-tailed)

was not completely task irrelevant. That is to say, although the effect was redundant—as participants had sufficient information to evaluate their performance without it—it was related to the task of stamping the circle. While Experiment 2 clearly shows that an effect does motivate beyond mere outcome feedback (a running score), whether a *completely* task irrelevant effect will do the same awaits further research.

How might having an effect motivate?

At our current level of knowledge, we can only speculate about the mechanism that translates control, and specifically effects, into motivation. By way of analogy, we propose that the way in which having an effect is motivating resembles the process of reinforcing the response that produced the effect. We stress, however, that such reinforcement comes from the event being judged as feedback about successful control and hence the hypothesized mechanism by which effects motivate is different from both classic and current notions of reinforcement. Operant conditioning, for example, is the process of learning a relation between a stimulus and response that delivers a *valued* outcome. Our findings are inconsistent with such outcome feedback being the critical factor. Specifically, the performance difference between the Effect and No Effect conditions holds even when feedback on obtaining a desired end state or goal is equal (Experiment 3).

A more recent version of incentive theory is about the incentive value (‘wanting’) of the stimulus itself (Berridge 2007; Berridge and Robinson 1998). According to that theory, the stimulus itself motivates through the learned relationship between it and a natural reinforcer (a valued outcome), which gives the stimulus its own incentive salience. Again, the main difference from this process is that the CEM hypothesis is that perceptual events judged to be effects are themselves reinforcers, over and above any current or past relationship with any primary or 'secondary reinforcement'.[8]

An offshoot of this is that any external or internal stimulus may become a sign for potential or actual control (control feedback) and thus motivate. In line with this idea, recent neuroscientific work has demonstrated that a stimulus that comes to indicate the opportunity for choice, another form of control effectiveness (Higgins 2012), activates the brain's 'reward system' and that this happens regardless of the outcome value of that choice (Leotti and Delgado 2011). Within the proposed framework, a stimulus indicating the opportunity (or necessity) of choice can be thought of as a strong signal that one has full control over the unfolding of the events—a kind of one-shot action–outcome contingency manipulation.

Classically, motivation has been parsed into two elements—action selection and effort allocation (Dickinson and Balleine 2002). Accordingly, motivation from control processes could affect performance by facilitating selection of control-relevant actions by increasing their accessibility or mental activation (Eitam and Higgins 2010; Eitam et al. 2012) and/or by a focal increase of effort (Bijleveld et al. 2009, 2010; Capa et al. 2011; Pessiglione et al. 2007). Further research is needed to establish which of these mechanisms underlie how control effects operate motivationally.

Why do effects motivate?

In a recent paper, we proposed that processing of external stimuli is influenced by the 'control relevance' of these stimuli (Eitam et al. 2012; Eitam and Higgins 2010). Specifically, we suggested that the mental representation of stimuli that are perceived to be of high control relevance (e.g., an effect of one's action) would be more accessible and will leave a stronger mark in the mind, for example, such stimuli will be learned better. This idea resonates with current ideas and findings from human and animal neuroscience that argues that the dopaminergic system is driven by 'epistemic' factors such as learning about potential effects one *could* attain in the current environment (Bromberg-Martin and Hikosaka 2009; Redgrave 2006; Redgrave et al. 2008). Further speculating, it may be that dopamine both marks the representation of control effects, thereby increasing their relevance and accessibility in memory, *and* reinforces the action plan that produced them increasing the chance that the action is selected (and the effect reproduced). Such a function would also answer the question of why task (or 'value')-irrelevant effects are learned (i.e., encoded) at all and would explain how the ideomotor principle could operate even without a conscious phase of action–effect contingency learning.

Implications of control effect as motivator

There are various social phenomena that are puzzling when human motivation is viewed strictly from the perspective of desired outcomes. Consider, for example, altruistic behavior. Recently, Choshen-Hillel and Yaniv (2011) have demonstrated an intriguing phenomenon: When people are given an opportunity to affect the fate of others, which is another way for having control, they are willing to sacrifice their own payment for others' payment. This is surprising when viewed solely in terms of desired outcomes, because these people are ending up with less payment (less outcome). But from the perspective of CEM, if people's involvement in the fate of others was represented by their mind as an instance of control, then it would be internally reinforcing to them.

Another question that CEM speaks to is the puzzle of habits (Allport 1937). Namely, why do people continue to persist in activities after they have lost their value? CEM suggests an answer—that these activities are still reinforced by the effects they bring, regardless of their (now non-existent) outcome value.

Effect as motivator may also have implication for physical and mental health, specifically for Parkinson's disease and schizophrenia. In Parkinson's, the neurons that are responsible for dopamine secretion die (Lang and Lozano 1998). Although initially considered a motor disease, more and more researchers see it today as a malfunctioning of the motivational system (Redgrave et al. 2010). Regarding CEM, the question is whether the malfunction concerns the muted benefit that Parkinson's patients get from having control effects (Redgrave and Gurney 2006; Redgrave et al. 2008). Moore et al. (2010) have recently demonstrated that an implicit measure of having a control effect—intentional binding—was intact for people suffering from Parkinson's while explicit judgments of authorship were not (i.e., they were positively correlated with dopamine agonist medication). Studies could use our task with Parkinson's patients to investigate whether having such a basic control effect would enhance performance in these patients. Such research could shed light on to what degree Parkinson's symptoms stem from the lack of reaping motivation from the effects.

[8] It is possible to describe an effect as being a desired outcome in itself. The point is that it is enough to be represented as an effect to be motivating, independent of whatever consequences follow.

In schizophrenia, which typically involves dopaminergic overactivity, there is evidence that people suffering from schizophrenia are impaired in their explicit judgments of authorship (Daprati et al. 1997). One possibility is that the motivational impact of having a control effect will be strengthened due to an increase in dopaminergic availability. The alternative possibility is that the difference between conditions will be actually decreased—because the hyperactivation of dopaminergic neurons will lead patients in the No Effect condition to imbue an effect where there is none (Moore et al. 2010). Thus, using CEM, it is possible to address both Parkinson's and schizophrenia as control-to-motivation disorders.

Acknowledgments This research was supported by a David C. McClelland Postdoctoral Fellowship and Grant 277/12 from the Israel Science Foundation (ISF) to Baruch Eitam and by Grant 39429 from the National Institute of Mental Health to E. Tory Higgins.

References

Abramson LY, Seligman ME, Teasdale JD (1978) Learned helplessness in humans: critique and reformulation. J Abnorm Psychol 87(1):49–74

Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50(2):179–211

Allport GW (1937) The functional autonomy of motives. Am J Psychol 50:15

Atkinson JW (1957) Motivational determinants of risk-taking behavior. Psychol Rev 64(6):359–372

Bandura A (1977) Self-efficacy: toward a unifying theory of behavioral change. Psychol Rev 84(2):191–215

Barnes GW, Kish GB (1961) Reinforcing properties of the onset of auditory stimulation. J Exp Psychol 62:164–170

Berridge KC (2007) The debate over dopamine's role in reward: the case for incentive salience. Psychopharmacology 191(3):391–431. doi:10.1007/s00213-006-0578-x

Berridge KC, Robinson TE (1998) What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? Brain Res Rev 28(3):309–369

Bijleveld E, Custers R, Aarts H (2009) The unconscious eye opener: pupil dilation reveals strategic recruitment of resources upon presentation of subliminal reward cues. Psychol Sci 20(11):1313–1315

Bijleveld E, Custers R, Aarts H (2010) Unconscious reward cues increase invested effort, but do not change speed-accuracy tradeoffs. Cognition 115(2):330–335. doi:10.1016/J.Cognition.2009.12.012

Bromberg-Martin ES, Hikosaka O (2009) Midbrain dopamine neurons signal preference for advance information about upcoming rewards. Neuron 63(1):119

Capa RL, Bustin GM, Cleeremans A, Hansenne M (2011) Conscious and unconscious reward cues can affect a critical component of executive control. Exp Psychol 58(5):370–375. doi:10.1027/1618-3169/a000104

Carver CS, Scheier MF (1990) Origins and functions of positive and negative affect: a control-process view. Psychol Rev 97(1):19–35

Choshen-Hillel S, Yaniv I (2011) Agency and the construction of social preference: between inequality aversion and prosocial behavior. J Personal Soc Psychol 101(6):1253–1261

Daprati E, Franck N, Georgieff N, Proust J, Pacherie E, Dalery J, Jeannerod M (1997) Looking for the agent: an investigation into consciousness of action and self-consciousness in schizophrenic patients. Cognition 65(1):71–86

David N, Newen A, Vogeley K (2008) The "sense of agency" and its underlying cognitive and neural mechanisms. Conscious Cogn 17(2):523–534

Dickinson A, Balleine B (2002) The role of learning in the operation of motivational systems. In: Gallistel CR (ed) Learning, motivation and emotion, vol 3. Wiley, London, pp 497–533

Eitam B, Higgins ET (2010) Motivation in Mental accessibility: relevance of a representation (ROAR) as a new framework. Soc Personal Psychol Compass 4(10):951–967. doi:10.1111/j.1751-9004.2010.00309.x

Eitam B, Higgins ET (2012) Being in control motivates beyond feeling in control. Unpublished manuscript

Eitam B, Miele DB, Higgins ET (2012) Motivated remembering: remembering as accessibility and accessibility as motivational relevance. In: Carlston D (ed) Handbook of social cognition. Oxford University Press, New York (in press)

Harlow HF, Harlow MK, Meyer DR (1950) Learning motivated by a manipulation drive. J Exp Psychol 40(2):228–234

Higgins ET (1997) Beyond pleasure and pain. Am Psychol 52(12):1280

Higgins ET (2012) Beyond pleasure and pain: how motivation works. Oxford University Press, New York

Hommel B (2009) Action control according to TEC (theory of event coding). Psychol Res Psych 73(4):512–526. doi:10.1007/S00426-009-0234-2

Hommel B, Musseler J, Aschersleben G, Prinz W (2001) The theory of event coding (TEC): a framework for perception and action planning. Behav Brain Sci 24(5):849–937

James W (1890) The principles of psychology. Harvard University Press, Cambridge, MA

Lang AE, Lozano AM (1998) Parkinson's disease. First of two parts. N Engl J Med 339(15):1044–1053. doi:10.1056/NEJM199810083391506

Leotti LA, Delgado MR (2011) The inherent reward of choice. Psychol Sci. doi:10.1177/0956797611417005

Lewin K (1935) A dynamic theory of personality: selected papers. MacGraw-Hill, New York

Miller GA (1960) Plans and the structure of behavior. Holt, New York

Moon LE, Lodahl TM (1956) The reinforcing effect of changes in illumination of lever-pressing in the monkey. Am J Psychol 69(2):288–290

Moore JW, Schneider SA, Schwingenschuh P, Moretto G, Bhatia KP, Haggard P (2010) Dopaminergic medication boosts action-effect binding in Parkinson's disease. Neuropsychologia 48(4):1125–1132. doi:10.1016/J.Neuropsychologia.2009.12.014

Moore JW, Middleton D, Haggard P, Fletcher PC (2012) Exploring implicit and explicit aspects of sense of agency. Conscious Cogn 21(4):1748–1753

Pessiglione M, Schmidt L, Draganski B, Kalisch R, Lau H, Dolan RJ, Frith CD (2007) How the brain translates money into force: a neuroimaging study of subliminal motivation. Science 316(5826):904–906. doi:10.1126/science.1140459

Prinz W (1997) Perception and action planning. Eur J Cogn Psychol 9(2):129–154

Redgrave P, Gurney K (2006) The short-latency dopamine signal: a role in discovering novel actions? Nat Rev Neurosci 7(12):967–975. doi:10.1938/Nrn2022

Redgrave P, Gurney K, Reynolds J (2008) What is reinforced by phasic dopamine signals? Brain Res Rev 58(2):322–339. doi:10.1016/J.Brainresrev.2007.10.007

Redgrave P, Rodriguez M, Smith Y, Rodriguez-Oroz MC, Lehericy S, Bergman H, Agid Y, DeLong MR, Obeso JA (2010) Goal-directed and habitual control in the basal ganglia: implications for Parkinson's disease. Nat Rev Neurosci 11(11):760–772. doi:10.1038/nrn2915

Seligman ME (1968) Chronic fear produced by unpredictable electric shock. J Comp Physiol Psychol 66(2):402–411

Shanks DR, Dickinson A (1991) Instrumental judgment and performance under variations in action-outcome contingency and contiguity. Mem Cogn 19(4):353–360

Shin YK, Proctor RW, Capaldi E (2010) A review of contemporary ideomotor theory. Psychol Bull 136(6):943

White RW (1959) Motivation reconsidered: the concept of competence. Psychol Rev 66:297–333