Directive and Incentive Functions of Affective Action Consequences: An Ideomotor Approach

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Abstract

Five experiments examined whether affective consequences become associated with the responses producing them, and whether anticipations of positive and negative action outcomes influence action control differently. In a learning phase, one response produced pleasant and another response unpleasant visual effects. In a subsequent test phase, the same actions were carried out in response to a neutral feature of affective stimuli. Results showed that responses were faster when the irrelevant valence of the response cue matched the valence of the response outcome, but only when the responses still produced outcomes. These results suggest that affective action consequences have a directive function in that they facilitate the selection of the associated response over other responses, even when the response outcome is unpleasant (Experiment 4A). Results of another experiment showed that affective action consequences can also have an incentive function in that responses with pleasant outcomes are generally facilitated relative to responses with unpleasant outcomes. However, this motivational effect was seen only in a free-choice test (Experiment 5). The results suggest that behavioral impulses induced by ideomotor processes are constrained by the motivational evaluation of the anticipated action outcome. A model that integrates motivational factors into ideomotor theory is presented.

Keywords: goal-directed action; instrumental learning; action-effect acquisition; ideomotor theory; incentive motivation;

Introduction

Instrumental actions are those that are performed for their effects or consequences. Ideomotor theory proposes that these consequences become associated with the preceding movements in memory, and that in turn the sensory effect is used to select, initiate, and control an action (Greenwald, 1970; Hommel, Müsseler, Aschersleben, & Prinz, 2001; Kunde, Elsner, & Kiesel, 2007). Supportive of this claim, numerous studies showed (i) that perceptions of action consequences become associated with the producing movements in memory, (ii) that knowledge of the sensory effect is automatically retrieved from memory during action selection, and (iii) that anticipated sensory effects are causally involved in the production and control of a motor response (for reviews see Hommel, 2013; Nattkemper, Ziessler, & Frensch, 2010; Shin, Proctor, & Capaldi, 2010). However, while ideomotor theory provides an elegant account of how an intended outcome is translated into overt behavior, it does not explain why that particular outcome was chosen to control the action in the first place. Accordingly, not much is known about the motivational processes that determine whether an anticipated outcome becomes a goal to be pursued, and how anticipations of motivationally relevant consequences of actions affect voluntary action control. The present article focuses on this issue.

In line with ideomotor theory, we hypothesized that affective action consequences become associated with the producing movements in memory just like other, nonaffective consequences. Retrieving the affective outcomes from memory should then automatically elicit the associated response, producing an ideomotor effect. Following instrumental learning theory (Shanks, 1993), we additionally expected that an action tendency is influenced by the hedonic value of the anticipated action outcome: an anticipated pleasant outcome should potentiate the evoked response tendency, while the retrieval of an unpleasant outcome should inhibit the corresponding action. In short, motivational evaluations of anticipated action consequences were hypothesized to constrain behavioral impulses induced by ideomotor processes, enhancing responses that produce pleasant consequences while suppressing those that generate unpleasant consequences.

Directive Function of Action Consequences

People must learn the consequences of behaviors before they can engage in voluntary action. Elsner and Hommel (2001) proposed a two-stage model of action-effect learning that explains a gradual emergence of action control through associative learning of the sensory effects that are generated by the response. First, an association is formed between the representation of a movement and the representation of the sensory consequence that follows the movement regularly and closely in time. Due to the bidirectionality of the associative link, the sensory effect can then act as a retrieval cue for the associated movement pattern. As a result, movements can be selected and initiated by anticipating their outcomes, that is, by retrieving wanted effects from memory, which spreads activation to the associated response.

For an empirical test of their model, Elsner and Hommel (2001) introduced a learning paradigm in which participants could freely choose between two response keys, each producing a different tone. In a subsequent test phase, they were to respond to the tones that were previously presented as response-contingent effects by pressing the key that had produced either the same tone (compatible action-effect) or a different tone (incompatible action-effect) in the learning phase. Results showed that the response key was pressed faster (in a forced-choice test situation) and more frequently (in a free-choice test situation) when the response effect was compatible with the response cue, even when the responses no longer produced tones in the test phase (i.e., under extinction). These findings confirm that a behavioral response is triggered automatically by activating its associated effect in memory.

Most important for our present concern, ideomotor theory was also extended to affective sensations that are registered after a behavioral response. Using a very similar learning paradigm, Beckers, De Houwer, and Eelen (2002) showed in a study that affective sensations that follow contingently upon the execution of a response become associated with this response, and that response selection is facilitated by affective stimuli that match the affective consequence in valence. In an acquisition phase, one of two hand movements was consistently followed by a mild but aversive electric shock, whereas the other movement was never followed by a shock. In a subsequent forced-choice test, the trained movements were emitted in response to a neutral feature of affective words. Results showed that the shock-generating movement was selected faster in response to negative than to positive words, whereas the other movement was initiated faster in response to positive than to negative words. In line with the model of Elsner and Hommel (2001), this compatibility effect suggests that the affective stimuli have primed the representation of a corresponding response outcome, which in turn activated the associated response via a bidirectional association between the representation of the response and the representation of the affective outcome. According to this interpretation of the results, an affective sensation is able to direct action selection by virtue of being a sensory effect that is contingent upon a response. Note, however, that this study is not conclusive about whether the compatibility effect was driven by associations with positive and negative action outcomes to the same extent. Furthermore, the study presented only an aversive action outcome (i.e., a shock), and a pleasant action outcome was manipulated only indirectly by the omission of an aversive shock (Rescorla, 1969). Given that the affective action consequences in this study were based on the (non)delivery of an electric shock, it is not clear whether the results can be generalized to affective outcomes that are not based on the presence and absence of a specific (sensory) event. Hence, the conclusion that ideomotor effects were demonstrated for positive *and* negative action consequences should be taken with some caution.

Incentive Function of Action Consequences

The study of Beckers and colleagues (2002) suggests that affective consequences become associated with the producing movements in memory just like other, nonaffective consequences. Once linked to a movement, retrieving the affective outcome from memory automatically reinstates the associated behavior. The implication is that the cognitive anticipation of an unpleasant event, once learned as an action effect, primes the associated behavior that generates this event. It is clear that this behavioral impulse is highly dysfunctional for an action control system that is aimed at an avoidance of aversive consequences and punishments (Eder & Hommel, 2013). Thus, for a motivational control of behavior, action control must be constrained by an additional process that is sensitive to the needs and desires of the person.

Evidence for such a motivational process comes from the extant animal and human literature on reinforcement and reward learning (Berridge, 2001; Toates, 1986). Studies are abundant showing that the motivational strength of a behavioral response increases if the response is followed by pleasure or a reward but decreases if the response is followed by displeasure or punishment (*law of effect*; Thorndike, 1911). While early theories assumed that a reinforcer only “stamps in” an association between a stimulus and a response without being itself included in the associative structure (Walker, 1967), it is now clear, based on work in a variety of laboratories, that this early conception is incorrect (de Wit & Dickinson, 2009; Hall, 2002; Rescorla, 1998). Instead, devaluation studies convincingly showed that a reinforcer becomes an integral part of the cognitive structure that controls an instrumental response, and that is anticipated with the execution of a specific response (see e.g., Adams & Dickinson, 1981; Colwill & Rescorla, 1985; Klossek, Russell, & Dickinson, 2008).

Based on reinforcement learning theory, one thus may expect that the hedonic implication of the anticipated effect has an additional influence on action control, facilitating those responses that are associated with pleasant outcomes while inhibiting those that are followed by unpleasant outcomes. In line with this expectation, Beckers and colleagues (2002) indeed observed that a shock-generating movement was also generally initiated more slowly than the alternative movement that was never followed by a shock. Even though not discussed by the authors in this way, this finding suggests that the execution of the response that produces an unpleasant outcome is generally inhibited relative to the alternative response. This motivational effect was however observed only in one of two experiments, suggesting that there are boundary conditions for this effect that are still unknown. Furthermore, it cannot be ruled out that participants postponed the receipt of an aversive shock in the test phase strategically by intentionally delaying the shock-producing response (Hineline, 1970).

To summarize, published research into affective action-effect learning suggests an operation of two different action control processes: (1) an ideomotor process in which stimuli can activate the representation of the affectively congruent outcome that in turn activates the corresponding response (leading to an affective congruency effect between the stimuli and the action outcome), and (ii) a motivational process that facilitates a response causing a pleasant outcome and/or inhibits a response causing an unpleasant consequence (producing a main effect of response outcome). The first process may implement a *directive* function that guides behavior towards an anticipated sensory effect, whereas the second process may realize an *incentive* function that adjusts the behavior to the needs and desires of the individual. However, little is known about how both processes work together during action control, and under which conditions motivational effects come to constrain behavioral impulses induced by an ideomotor process. The present research aims to fill this knowledge gap by analyzing action tendencies separately for pleasant and unpleasant action outcomes, and by comparing conditions that affect motivational and ideomotor processes differently.

The Purpose of the Present Research

The present research tests the idea that affective sensations that are registered after the execution of a response have a distinctive motivational effect on action control. Figure 1 shows an integration of motivation into a two-stage model of voluntary action control that is adapted from Elsner and Hommel (2001). In line with this model, it is assumed that codes representing the features of a movement become associated with the codes representing features of a contingently produced sensory event in a first stage. At this stage, links are also established to affective representations that encode the positivity and negativity (i.e., the value) of an expected outcome (see the upper panel of Figure 1). These value codes are assumed to be independent of the specific sensory or motor codes specifying stimuli, outcomes, and motor responses (Liu, Hairston, Schrier, & Fan, 2011; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). The result of this learning process is a rich associative network that connects codes representing motor patterns with codes of perceived action effects and codes of their affective values. Activating a feature code that is part of this network will then tend to activate the whole network to some degree, including its motor part. As a result, a movement is aroused by anticipating (i.e., activating the codes of) their consequences in a second stage, including the anticipation of affective action consequences (Melcher, Weidema, Eenshuistra, Hommel, & Gruber, 2008; Knutson & Greer, 2008).

In addition to being an anticipated action effect, the affective valence of an effect also has a motivational effect on action generation by affecting the spread of activation to motor codes (see the lower panel of Figure 1). There are at least two different possibilities of how the affective valence of an anticipated effect may influence ideomotor processes:

(1) According to a gatekeeper model, ideomotor action is *mediated* by the affective value of an anticipated action consequence: Activation can spread from effect codes to motor codes if the anticipated consequence is positive but access to these codes is blocked if the anticipated outcome is negative. As a consequence, only responses that cause positive outcomes are selected in an ideomotor fashion.

Suggestive evidence for a gatekeeper-model comes from studies on freezing responses to negative stimuli. Many studies have shown that animals and humans "freeze" or slow down movement following the detection of (close) negative stimuli (e.g., Blanchard, & Blanchard, 1969; Hagenaars, Stins, & Roelofs, 2012). Notably, a freezing response has been linked to inhibitory processes at the level of response execution rather than response selection (Wilkowski & Robinson, 2006). According to this account, an individual can choose between different courses of action in a threatening situation, but the action is executed in a very slow and cautious manner. A related process may also be involved in the (conditioned) suppression of a response that has a history of punishment (Bouton & Bolles, 1980). Thus, anticipating a negative action consequence may make an individual “freeze” by blocking access to the associated motor codes.

(2) An alternative proposal is that a motivational process operates in addition to and independently from an ideomotor process. According to this “additive” model, ideomotor action is *moderated* by the affective value of an anticipated effect: A response that produces a negative outcome is motivationally suppressed relative to a response that produces a positive outcome. As a result, a behavioral impulse induced by an ideomotor process is enhanced by the motivational process if the response outcome is positive, whereas the impulse is neutralized by the motivational process if the anticipated outcome is negative.

The present experiments were designed to test predictions of these models (for an overview see Figure 2). As explained above, both models predict that ideomotor effects are enhanced with positive response outcomes relative to negative response outcomes. This hypothesis was tested with experiments that paired responses with pleasant and unpleasant outcomes in a first phase, and that primed these affective outcomes through presentations of affective stimuli in a second phase. Notably, many different visual stimuli were presented as affective response effects, making sure that the action outcomes did not differ on dimensions other than affective valence. In line with the models described above, we expected an ideomotor effect (i.e., an affective compatibility effect between response cue and response outcome) with responses that caused pleasant experiences but no effect or a markedly reduced effect with responses that produced unpleasant experiences.

A subsequent experiment sought to distinguish between both models by making comparisons with a baseline condition in which actions were carried out in response to neutral stimuli. According to the additive model, positive stimuli should prime responses associated with pleasant outcomes and negative stimuli should prime responses associated with unpleasant outcomes relative to their baseline conditions. The gatekeeper model, in contrast, predicts only a priming of a response that is associated with a pleasant outcome. Thus, finding evidence that negative stimuli facilitate responses associated with an unpleasant outcome relative to a neutral baseline condition would be incompatible with the gatekeeper model.

A final experiment tested more specific predictions of the additive model. According to this model, a motivational effect should be observed in addition to an ideomotor effect. Forcing participants to generate pleasant and unpleasant action consequences in a speeded reaction time task however likely underestimates a motivational effect because the incentive influence of the action outcome needs to counteract the effects of the S-R instructions (De Wit & Dickinson, 2009; see also Herwig, Prinz, & Waszak, 2007). We therefore replaced a forced-choice test with a free-choice test, in which participants were free to choose between a response associated with a pleasant or an unpleasant outcome. In line with the additive model, it was expected that participants prefer the response that generates a pleasant outcome (indexing a motivational or incentive effect), especially when a positive stimulus is present on the screen (indexing an ideomotor or directive effect).

In addition to these specific hypotheses, additional conditions were examined that may affect the acquisition and/or retrieval of learned action-effects as well. One variable of interest is the robustness of the acquired associations to an extinction treatment. While the extinction of an instrumental response is a standard finding when motivationally relevant outcomes follow a behavior (e.g., food; for a review see Bouton, 1994), it is striking that studies on human action-effect acquisition that presented affectively neutral action outcomes (e.g., high and low tones) observed a robust action-effect retrieval even after a large number of extinction trials (e.g., 100 trials; Elsner & Hommel, 2001). Extinction may thus affect motivational and ideomotor effects differently. In one condition of our experiments, the responses generated the same affective outcomes in the test phase as in the acquisition phase; in a second condition, the responses no longer produced outcomes in the test phase (extinction test). With these conditions, we were able to examine the robustness of a learning effect, and whether motivational and ideomotor effects are extinguished at different rates.

A second variable of interest is the participants' awareness of the contingency between the responses and their affective consequences. According to the current theorizing, affective action outcomes should influence response selection even without an explicit intention to generate these outcomes and/or to retrieve these outcomes. Hence, an effect of positive and negative action outcomes on action control should be observed even when the participant cannot report the correct contingency between the responses and their affective consequences in a post-experimental questionnaire.

Experiments 1 to 3

Three experiments were modeled after the general task procedure that was used by Beckers and colleagues (2002, Experiment 1) to study a learning of affective action consequences and their retrieval in a test phase. Figure 2 shows the design of these experiments. In the acquisition phase, participants were free to press a left or right response key in a random order provided that each response was performed about equally often. One key consistently produced a pleasant visual effect (word or picture), whereas the other key consistently produced an unpleasant visual effect on the computer screen. In the test phase, the same response keys were used to respond to a neutral feature of affective words or pictures. In one test condition, the responses continued to produce affective consequences; in the other test condition, affective response outcomes were no longer presented (extinction test). After the test phase, participants were probed for their awareness of the contingencies between the responses and the affective consequences.

Experiment 1 used affective words as stimuli and response outcomes, Experiment 2 presented affective words as response cues and affective pictures as response outcomes, and Experiment 3 used affective pictures only. Given that these experiments differed only in minor procedural details, we will report them together.

Method

Participants

A total of 150 students (41 in Experiment 1, 44 in Experiment 2, and 65 in Experiment 3) with an age between 18 and 38 years (*M* = 22.3, *SD* = 3.2) participated in exchange for payment or for partial course credit. Eight participants were left-handed and 98 students were female. Individual performance was screened for (i) insufficient practice of one response in the acquisition phase (i.e., fewer than 25% presses of one key), and (ii) excessively high error rates in the test phase (more than 28% presses of the wrong response key; outliers according to Tukey, 1977). The first criterion led to the removal of two data sets from Experiment 1, two from Experiment 2, and one from Experiment 3. The second criterion led to the exclusion of eight more data sets, four from Experiment 1, two from Experiment 2, and two from Experiment 3. In total, data sets of 35, 40, and 62 participants remained for statistical analyses of Experiments 1, 2, and 3, respectively.

Design

Figure 2 gives an overview of the experiment design. Each experiment had a mixed 2 (response cue: positive vs. negative) x 2 (response outcome: positive vs. negative) x 2 (extinction: yes vs. no) factorial design, with response cue and response outcome being varied within participants and extinction being manipulated between groups. In addition, the following factors were counterbalanced across participants: (1) the assignment of pleasant and unpleasant effects to the left and right response keys; (2) the mapping of the response keys onto the neutral feature of the response cues in the test phase; (3) whether a stimulus set was presented as action effect or as response cue (in Experiments 1 and 3 only).

Apparatus and Material

Participants were seated at a distance of about 60 cm from a 17" VGA color monitor. Stimulus presentation and measurement of response latencies were controlled by a software timer with video synchronization (E-Prime; Psychology Software Tools, Inc.). Participants pressed the spacebar of a QWERTZ keyboard with the left hand and the enter key of the numerical board with the right hand.

Stimuli for Experiment 1 (word-word). Affective words were 100 adjectives and 100 nouns that were selected from a standardized word pool according to their evaluative ratings (Schwibbe, Röder, Schwibbe, Borchardt, & Geiken-Pophanken, 1981). Half of the nouns and adjectives were positive (M = 1.69; SD = 0.59), the other half were negative (M = -1.84; SD = 0.54). The positive and negative words did not differ in their number of letters (range: 4–12) and in their arousal ratings (with both ps > .18). The stimuli were divided into two sets: one word set was presented as response outcomes, the other set cued the response in the test phase. An additional 16 words (8 adjectives, 8 nouns) were selected for task practice. All words were presented in lower case letters (Courier New 18 pt) at the center of the screen.

Stimuli for Experiment 2 (word-picture). Response outcomes were 50 positive (M = 7.77; SD = 0.27) and 50 negative pictures (M = 2.19; SD = 0.43) that were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). The subsets of pleasant and unpleasant pictures did not differ in arousal ratings (F < 1). The pictures were displayed in full screen mode. Response cues were 50 nouns and 50 adjectives that were selected from the standardized word pool (Schwibbe et al., 1981). Half of the words were positive (M = 1.85; SD = 0.58), the other half was negative (M = -2.07; SD = 0.49). The positive and negative words did not differ in the number of letters (range: 4–12) and in arousal ratings (all Fs < 1). An additional 16 words (8 adjectives, 8 nouns) and 16 pictures (8 positive, 8 negative) were selected for task practice.

Stimuli for Experiment 3 (picture-picture). Ninety-six pictures were selected that depicted either human persons or animals, most of them were taken from the IAPS. Half of the person and animal pictures portrayed clearly negative scenes (e.g., mutilated body, attacking animal), the other half showed clearly positive scenes (e.g., babies, puppies). The stimuli were split into two picture sets: one set was presented as response outcomes, the other set was used for the response cueing in the test phase. An additional 16 pictures (8 animal, 8 person) were selected for task practice. Pictures that followed a keypress were displayed in full screen mode; pictures that cued a response were reduced to 75% of the original size.

Procedure

Each experiment consisted of two phases: an acquisition phase and a test phase. For the acquisition phase, participants were instructed to press one of the response keys as quickly as possible after a white box has disappeared from the screen. **[1]** They could choose freely between the two responses but they were advised to press the keys in random order and about equally often. Each key press triggered the presentation of an affective word (Experiment 1) or of an affective picture (Experiments 2 & 3). Participants were not informed about the contingency between the responses and the affective outcomes; rather, task instructions stated that the stimuli following a key press are irrelevant for the task at hand and should hence be ignored.

In the acquisition phase, a white box (250 pixels wide and 150 pixels high) was shown for 200 ms at the centre of the screen. Then, the program waited up to 1,000 ms for a response. If a response was made, and after a delay of 50 ms, a pleasant or unpleasant word or picture was presented for a fixed duration (300 ms in Experiment 1, 400 ms in Experiment 2, and 500 ms in Experiment 3). In trials with no response or with anticipatory responses (i.e., a response prior to or during the presentation of the white box), an error message appeared instead of a response-effect. The next trial was initiated after 1.5 seconds.

Participants worked through 8 practice trials and 200 acquisition trials. After each block of 50 trials, a block summary appeared that informed the participant about the ratio of left and right key presses. Erroneous trials were repeated at a random position after the last trial block.

In the test phase, participants were informed that a word would now appear inside the white box (Experiment 1 & 2) or that a picture would now appear instead of a white box (Experiment 3). Participants were to classify the grammatical status of the word (noun vs. adjective) or the picture content (animal vs. person) according to fixed response mapping rules (see Study Design). Again, the response should be emitted as soon as possible after the white box (presentation duration: 200 ms) or picture (presentation duration: 300 ms) had disappeared but not earlier. An error message appeared when the response was anticipated (i.e., emitted before the response cue had disappeared from the screen), incorrect, or omitted (i.e., no response within 1 second). For half of the participants, the response key triggered the same affective effect as in the acquisition phase; for the remaining participants the screen was blank for the same time period (i.e., extinction). Participants were not explicitly informed about the fact that the responses would no longer produce effects in the extinction test condition. In all other respects, the sequence of events in test and acquisition trials was identical.

In the test phase, participants worked through 8 practice trials and 100 experimental trials (Experiment 3: 96 trials). In half of the trials, the affective response cue was compatible with the affective response effect (i.e., positive-positive; negative-negative); in the other half of the trials the valence was incompatible (i.e., positive-negative; negative-positive). Again, erroneous test trials were repeated at a random position after the last trial to ensure a sufficient number of valid trials.

After the test phase, participants were probed for awareness of the contingency between the responses and the affective effects. Participants typed answers to the following questions into the keyboard: (i) “Which hypotheses do you think were investigated in this study?” (ii) “Did you recognize a systematic pattern between the key press and the following word (picture)?" (iii) "Did the Enter key produce positive or negative words (pictures)?" (iv) "Did the space bar produce positive or negative words (pictures)?" (v) "Did you pursue a strategy to improve the word (picture) classification?" At the end of the experiment, participants were thanked, debriefed, and paid for participation.

Results

Acquisition Phase

After excluding trials with response omissions (Experiment 1: 2.7%; Experiment 2: 0.7%; Experiment 3: 2.8%) and anticipatory responses (Experiment 1: 3.9%; Experiment 2: 5.8%; Experiment 3: 4.9%), the proportion of left and right keypresses was calculated for each experiment. As revealed by mixed analyses of variance (ANOVA) of the response proportions with response key (key assigned to the dominant vs. the non-dominant hand) as within-factor and outcome assignment to the response hand (positive to the dominant hand vs. positive to the non-dominant hand) as between-variable, participants pressed the key assigned to the dominant hand more frequently (M = 51%) than the key assigned to the non-dominant hand in Experiment 1, $F(1, 33) = 6.64$, $p < .05$, irrespective of the assigned affective outcome ($F < 1$). In Experiments 2 and 3, the response keys were pressed about equally often, regardless of the produced outcome (with all ps > .10).

Test Phase

Trials with response omissions (Experiment 1: 1.3%; Experiment 2: 0.9%; Experiment 3: 0.9%), anticipatory responses (Experiment 1: 0%; Experiment 2: 0%; Experiment 3: 2.3%), and incorrect responses (Experiment 1: 8.0%; Experiment 2: 7.9%; Experiment 3: 8.4%) were removed from reaction time analyses. In addition, Tukey (1977) outlier thresholds were computed for each experiment to identify response latency outliers; this truncation removed 2.1%, 3.0%, and 1.1% of the trials in Experiment 1, 2, and 3, respectively.

A combined analysis was performed that collapsed the data of the three experiments (n = 137). Reaction times and error rates were then analyzed with a mixed ANOVA that included the valence of the response cue and the valence of the response outcome as within-subject factors and extinction and experiment as between-subject factors. For all analyses, the significance criterion was set to $p < .05$ (two-tailed). Table 1 shows the means and standard deviations in each experiment condition.

Reaction times. The main effect of experiment reached significance, $F(2, 131) = 55.72$, $p < .001$. Participants classified pictures (animal-person decision in Experiment 3) about 123 ms faster than words (noun-adjective decisions in Experiments 1 & 2). The main effect of response cue was also significant: Participants responded to positive stimuli about 10 ms faster than to negative stimuli, $F(1, 131) = 29.02$, $p < .001$. The main effect of extinction was near significance, indicating slower responses when response outcomes were still presented during the test phase ($M = 592$ ms) compared to when they were not ($M = 571$ ms), $F(1, 131) = 2.97$, $p = .09$. More importantly, the interaction between the valence of the response cue and the valence of the response outcome was significant, $F(1, 131) = 5.38$, $p < .05$. This affective compatibility effect however interacted with the extinction condition, $F(1, 131) = 12.17$, $p < .001$. Comparisons of the means in each subcondition revealed a significant compatibility effect when affective response outcomes were still presented in the test (compatible trials: $M = 573$ ms; incompatible trials: $M = 584$ ms), $t(67) = -3.7$, $p < .001$. No compatibility effect was observed in the extinction condition (compatible trials: $M = 557$ ms; incompatible trials: $M = 553$ ms; $t < 1$). In the condition with response outcomes in the test phase, a compatibility effect was significant only with responses that produced pleasant outcomes (compatible trials: $M = 569$ ms; incompatible trials: $M = 589$ ms), $t(67) = 4.85$, $p < .001$; in contrast, no compatibility effect was observed with responses producing unpleasant outcomes (compatible trials: $M = 577$ ms; incompatible trials: $M = 580$ ms, $t < 1$). Thus, the ideomotor effect was restricted to responses with pleasant consequences.

The main effect of affective response outcome ($F < 1$) and the two-way interactions of this factor with extinction ($F < 1$) or experiment, $F(2, 131) = 1.30$, $p = .28$, were not significant.

Thus, there was no indication that the response producing an unpleasant outcome was initiated more slowly than the response that generated a pleasant outcome, even though the power of the combined test to detect a small effect ($d = 0.2$) was still acceptable ($P = .75$).

Block Analysis. To examine whether a compatibility effect becomes stronger in the condition with presentations of outcomes in the test phase and/or weaker in the extinction condition following the acquisition phase, a block analysis was performed that subdivided the test trials into five blocks. Then, compatibility effects were computed for each subblock by subtracting the response time in compatible trials from the response time in incompatible trials (i.e., compatibility effect = $M_{incompatible}$–$M_{compatible}$). Effect scores were then entered into a mixed ANOVA with the factors trial block, extinction, and experiment. This analysis yielded a main effect of experiment, $F(2, 131) = 3.23$, $p < .05$, indexing an enhanced compatibility effect in Experiment 1 compared to Experiments 2 and 3. The main effect of extinction was also significant, $F(1, 131) = 14.34$, $p < .001$, corroborating the results of the analyses described above. Most important, none of the effects involving the block factor were significant (with all *p*s > .10). Furthermore, the linear trend of the block factor and the interaction with extinction were not significant (with both *F*s < 1), suggesting that the compatibility effect did not increase or decrease linearly with trial blocks, irrespective of whether response outcomes were presented in the test phase or not. Planned *t*-tests of the effect scores against zero (one-tailed) for each trial block revealed significant effects in every block when outcomes were presented in the test phase; however, compatibility effects did not differ from zero or were even reversed in direction (in the third trial block) in the extinction test. Overall, these results confirm robust compatibility effects when affective outcomes were still presented in the test phase, while no reliable effects were observed in the extinction test.

Contingency Awareness. An additional analysis examined an influence of contingency awareness on the size of the compatibility effect. For this analysis, participants were identified as “aware” when they indicated the correct assignment of positive and negative outcomes to the keys in any of the final questions. Using this scoring method, 34%, 63%, and 58% of the participants in Experiment 1, 2, and 3, were scored as being aware. **[2]** The ratios of aware participants were about equal in the conditions with and without outcome presentation in the test (55% and 51%), $\chi^2(1, N = 137) = 0.18$, $p = .67$. An ANOVA of the compatibility effects with contingency awareness, extinction test, and experiment as factors yielded only a significant main effect of extinction, $F(1, 125) = 8.15$, $p < .05$. Compatibility effects were numerically enhanced when participants were unaware of the R-O relationship; however, the main effect of contingency awareness and all other tests involving this factor did not reach significance (with all *p*s > .10). In short, explicit knowledge of the R-O contingency had no effect on the affective compatibility effect, even though the probabilities to detect an effect with a large ($f = 0.40$; $p = .99$) or medium size ($f = 0.25$; $p = .83$) were sufficient according to a post-hoc power analysis (conducted with G*Power 3; Faul, Erdfelder, Lang, & Buchner, 2007). **[3]**

Error rates. In the ANOVA of the error rates, the three-way interaction between response cue, response outcome, and extinction approached significance, $F(1, 131) = 2.85$, $p = .09$. In line with the results of the reaction time analyses, errors were more frequent in incompatible trials ($M = 8.7\%$) than in compatible trials ($M = 7.8\%$) but only when response outcomes were still presented during the test. The three-way interaction between response cue, response outcome, and experiment was also significant, $F(2, 131) = 4.13$, $p < .05$. The affective compatibility effect reached significance in Experiment 3, $t(61) = 2.25$, p < .05, but not in Experiments 1 and 2 (see Table 1). No other effects were significant (largest $F = 2.03$, all *p*s > .15).

Discussion

The results can be summarized as follows: First, there was no main effect of the valence of the response outcome. Participants did not press the key that produced pleasant experiences faster than the key that generated unpleasant experiences. Thus, the present experiments failed to show an incentive effect of pleasant action outcomes. It should be noted that this failure was not unexpected given that participants were motivationally prepared to generate unpleasant action outcomes when they agreed to participate in our experiments.

Second, the experiments yielded clear evidence for a directive function of the affective response outcomes: the responses were carried out faster when the affective experience they produced was compatible with the affective meaning of a response cue than when it was not. This finding replicates an affective compatibility effect first observed by Beckers and colleagues (2002), and it supports an extension of ideomotor theory to affective response outcomes.

Notably, no compatibility effect was observed in an extinction condition in which response outcomes were not presented during the test phase. This finding was unexpected given that prior studies on human action-effect acquisition in the sensory domain have observed robust action-effect priming even after a large number of extinction trials (e.g., 100 trials; see Elsner & Hommel, 2001). From the perspective of more traditional research on instrumental learning, the extinction of an operant response is, however, less surprising given that extinction is typically observed in instrumental learning. Nevertheless, even from this perspective, one would expect a retrieval of learned action-effects and thus a compatibility effect in the very first block of the extinction test, which was not observed. It should be noted, however, that participants worked first through a practice phase in which no response outcomes were presented. Thus, it is possible that the affective response outcomes were rapidly extinguished in the practice trials before the start of the test trials. **[4]**

Third, and most important for the present discussion, affective response cues triggered a corresponding response only when the response produced a pleasant outcome, but not when the responses caused unpleasant outcomes. Latter finding is in line with the idea that the affective valence of an anticipated effect constrains ideomotor processes.

The absence of a compatibility effect with responses that produced unpleasant outcomes may suggest that negative stimuli do not prime these responses, thus supporting the gatekeeper model. However, one must be careful with this interpretation, because the compatibility relation is confounded with differences in the processing speed of the response cues. In fact, responses to positive stimuli were generally faster than to negative stimuli, which is in line with other research showing that positive information is processed faster than negative information (Unkelbach, Fiedler, Bayer, Stegmüller, & Danner, 2008). Thus, it is possible that negative stimuli did prime the compatible negative response, as predicted by an additive model, but that this priming effect was masked by a facilitated processing of positive stimuli. Alternatively, it is possible that associations with negative action outcomes were not acquired and/or less consolidated in memory relative to associations with positive outcomes. Thus, several explanations are possible why the compatibility effect was restricted to pleasant response outcomes in these experiments.

Experiment 4

To evaluate these possibilities, we conducted an additional experiment that included a neutral baseline condition for a comparison. The setup was identical with Experiment 2 with the major change that participants responded to neutral words in addition to positive and negative words. By comparison with a baseline condition (neutral words), priming effects could be computed separately for responses generating positive and negative outcomes, eliminating the confounding of priming effects with differences in the processing speed of positive and negative stimuli. Given that an ideomotor (compatibility) effect was observed in the previous experiments only with outcome presentations in the test phase, an extinction condition was not included in this experiment.

The additive model and the gatekeeper model make different predictions for this experiment. According to the gatekeeper model, only a response that is associated with a positive outcome is selected in an ideomotor fashion. Accordingly, a priming effect is expected for the response that produces a positive outcome but not for the response that produces a negative outcome. The additive model, in contrast, expects a priming effect with both responses. Evidence that negative stimuli (relative to neutral stimuli) facilitate responses causing negative outcomes would consequently argue against the gatekeeper model but be in line with the additive model. Furthermore, this finding would confirm that negative consequences of actions can be acquired and retrieved from memory just like their positive counterparts.

In addition to Experiment 4A, two control experiments were conducted. Experiment 4B examined the importance of learning for the compatibility effect obtained in the test phase by presenting the same test phase as in Experiment 4A but this time without action-effect learning in an acquisition phase. Thus, Experiment 4B was identical with Experiment 4A with the single change that no acquisition phase was presented prior to the test. According to a two-stage model of action control, action outcomes must be learned in a first stage (during the acquisition phase) for their retrieval in a second stage (during the test phase). If a compatibility effect is observed in Experiment 4A (with acquisition phase) but not in Experiment 4B (without acquisition phase), this difference would hence confirm that previously learned action outcomes are retrieved during the test.

Experiment 4C was conducted to control for differences in the processing of affective words relative to neutral words in the absence of response associations. If the selection of a response to negative words is facilitated by a response association with an affectively congruent (unpleasant) outcome, as suggested by an additive model, then negative word judgments should be facilitated more in the priming condition of Experiment 4A than in a corresponding control condition in which the same words are categorized without associations to response outcomes. This comparison allows for a more conservative test of ideomotor effects engendered by positive and negative action outcomes.

Method

Participants

Participants in Experiment 4A were 41 volunteers (25 women) with an age between 18 and 49 years (*M* = 22.1, *SD* = 4.8). Four participants were left-handers. None had participated in the previous experiments. The data of one participant were removed because she pressed only a single key during the acquisition phase. An additional 80 students (51 women; 11 left-handers; age: *M* = 22.2 years, *SD* = 2.6) participated in Experiment 4B (*n* = 40) and Experiment 4C (*n* = 40). Three participants in Experiment 4B responded incorrectly in more than 21% of the test trials (rest of the sample: *M* = 8.4%, *SD* = 4.0) and were identified as outliers according to Tukey (1977). One participant in Experiment 4C pressed the wrong key in 31% of the trials (rest of the sample: *M* = 9.6%, *SD* = 5.7). These data sets were removed from the statistical analyses.

Stimuli

Response cues were 40 positive (*M* = 2.44; *SD* = 0.21), 40 negative (*M* = -2.44; *SD* = 0.34), and 40 neutral (*M* = 0.02; *SD* = 0.12) words that were selected according to their evaluative norms from the Berlin Affective Word List Reloaded (Vo, Conrad, Kuchinke, Urton, Hofmann, & Jacobs, 2009). Half of the words in each evaluative category were adjectives, the other half were nouns. The subsets of words were matched in the number of letters (range: 4-9) and syllables (both *F*s < 1). An additional 6 words (3 adjectives, 3 nouns) were selected for task practice. Response outcomes were 60 positive (M = 7.67; SD = 0.36) and 60 negative pictures (M = 2.29; SD = 0.51) that were selected from the IAPS (Lang et al., 2005) and that did not differ in arousal ratings (*F* < 1). The pictures were displayed in full screen mode.

Procedure

The procedure of Experiment 4A was identical with Experiment 2 except for the following changes: Neutral words were presented in addition to positive and negative words during the test phase. On the basis of their grammatical category, half of the neutral words demanded a press of the key that generated a pleasant visual effect (picture) on the screen; the remaining half required a press of the other key that produced an unpleasant picture. The picture was shown for 500 ms on the screen. An extinction condition was not implemented. The number of practice trials for the test phase was reduced to 6 trials and the number of test trials was increased to 120 trials. Erroneous test trials were not repeated. Furthermore, the questions that probed knowledge of specific response-effect contingencies had now a forced-choice format.

Experiment 4B was identical with Experiment 4A with the single change that participants did not work through an acquisition phase before the test phase.

Experiment 4C was identical with Experiment 4B with the exception that no response outcomes (affective pictures) were presented during the test phase. The postexperimental questionnaire only asked for hypotheses and judgmental strategies.

Results

Acquisition Phase

Trials with response omissions (1.7% of all trials) and anticipatory responses (6.0% of all trials) were excluded. A mixed ANOVA of the response proportion revealed a tendency to press the key assigned to the dominant hand more frequently (M = 52%, SD = 6.3) than the key assigned to the non-dominant hand, $F(1, 38) = 3.26$, $p = .08$. The assignment of the affective outcomes to the response keys had no effect ($F < 1$).

Test Phase

Trials with response omissions (Experiment 4A, 1.3%; 4B, 1.2%; 4C, 1.3%), anticipatory responses Experiment 4A, 0.3%; 4B, 0.1%; 4C, 0.04%), and incorrect responses (Experiment 4A, 10.0%; 4B, 8.4%; 4C, 9.6%) were removed from reaction time analyses. Analyses of the error rates were in line with the results of the reaction time analyses and are not reported here. Fifteen participants (37.5%) in Experiment 4A and fourteen participants (37.8%) in Experiment 4B were not aware of the contingencies between the responses and the affective outcomes as indicated by incorrect answers in the postexperimental questionnaire.

Experiment 4A. Reaction times and error rates produced in Experiment 4A are shown in Table 1. A mixed ANOVA of the reaction times with valence of the response cue (positive vs.

neutral vs. negative) and valence of the response outcome (pleasant vs. unpleasant) as within-subjects factors and contingency awareness as between-subject factor yielded a significant main effect of the valence of the response cue, $F(2, 76) = 17.84$, $p < .001$, and a significant interaction between response cue and response outcome, $F(2, 76) = 3.99$, $p < .05$. Participants responded generally faster to positive words ($M = 634$ ms, $SE = 10.7$) than to negative words ($M = 658$ ms, $SE = 10.0$, $p < .001$) and neutral words ($M = 663$ ms, $SE = 11.2$, $p < .001$). Reaction speed to negative and neutral words was however not different ($p = .47$). Furthermore, there was no difference in the speed of the responses associated with pleasant and unpleasant outcomes ($F < 1$), and in reaction to the neutral words more specifically ($t < 1$). Contingency awareness had no effect on the result pattern (all *p*s > .10).

For a further examination of the interaction effect, separate priming effects were computed for each condition by subtracting the speed of a response to neutral words from the speed of a corresponding response to positive and negative words. This computation yielded four priming indices (positive word–pleasant response outcome; negative word–pleasant response outcome; positive word–unpleasant response outcome; negative word–unpleasant response-outcome); a negative priming score indexed a facilitated response and a positive score indicated a response delay relative to the baseline condition. Tests against zero showed that positive response cues facilitated the selection of responses with affectively congruent (pleasant) outcomes ($M = -33$, 95% CI [-48, -18]) and, to a lesser extent, the selection of responses with incongruent (unpleasant) outcomes relative to the baseline condition ($M = -27$, 95% CI [-40, -14]), $t(39) = 4.49$, $p < .001$, and $t(39) = 4.13$, $p < .001$, respectively. Most important, negative response cues facilitated responses generating an unpleasant outcome relative to neutral response cues ($M = -17$, 95% CI [-30, -3]), $t(39) = 2.52$, $p < .05$, while responses producing positive outcomes were delayed relative to the baseline condition ($M = +5$, 95% CI [-9, +19]) ($t < 1$). This result pattern confirms a priming of unpleasant action outcomes by negative stimuli.

Experiment 4B. Reaction times and error rates obtained in Experiment 4B are shown in Table 1. In a corresponding ANOVA of the reaction times, only the main effect of the valence of the response cue reached significance, $F(2, 70) = 29.66$, $p < .001$. Like in Experiment 4A, participants responded fastest to positive words (M = 654 ms, SE = 13.0). Reaction speed to negative words (M = 681 ms, SE = 13.0) and neutral words (M = 693 ms, SE = 14.0) was however not different according to a conventional criterion ($p = .068$). Most important, the interaction between valence of the response cue and valence of the response outcome was not significant ($F < 1$). Responses producing affectively congruent outcomes (M = 667, SE = 13.0) were not faster than responses producing affectively incongruent outcomes (M = 667, SE = 12.2). Thus, while a clear compatibility effect was observed in Experiment 4A with acquisition phase prior to the test, no compatibility effect was observed in a corresponding test condition that lacked a learning phase prior to the test phase. This difference is also confirmed by a cross-experimental comparison of the compatibility effects, $t(75) = 1.68$, $p < .05$ (one-tailed).

Experiment 4C. A repeated-measures ANOVA of the reaction times to positive, negative, and neutral words revealed a clear positivity bias in the word judgments, $F(2, 76) = 47.79$, $p < .001$. Participants responded to positive words with greater speed (M = 645, SE = 8.9) than to negative words (M = 682, SE = 9.7, $p < .001$) and neutral words (M = 684, SE = 9.8, $p < .001$). There was no difference in the response speed to negative words and neutral words ($p = .88$).

For a comparison with the priming scores obtained for Experiment 4A, facilitation scores were computed separately for positive and negative word judgments by subtracting the response speed to neutral words from the speed of corresponding responses to positive and negative words. A negative value of the facilitation score indexes faster responses, while a positive value indexes slower responses relative to the baseline condition with neutral words. The priming scores obtained for Experiment 4A were then contrasted with a general facilitation of positive and negative word judgments (relative to neutral judgments) estimated from Experiment 4C.

Comparisons with priming effects engendered by positive response cues revealed no significant differences (with *p*s > .15). Comparisons with priming effects engendered by negative response cues produced a significant difference. As expected, participants responded faster to negative words when the responses produced an unpleasant outcome (Experiment 4A) relative to a test condition in which the responses produced no outcome (Experiment 4C), $t(77) = 1.79$, $p < .05$ (one-tailed). This difference suggests the response association with an unpleasant outcome has facilitated the selection of the response.

Discussion

The results are at odds with a gatekeeper model. According to this model, a spread of activation from effect codes to motor codes is blocked when the action effect is unpleasant. Experiment 4A however obtained evidence that negative response cues (words) facilitate the selection of a response producing an unpleasant outcome (picture) relative to neutral response cues. Thus, ideomotor effects were obtained with both responses, in contradiction to the gatekeeper model.

One possible objection against this interpretation is that our selection of affectively neutral words for a baseline comparison was inappropriate because responses to neutral words were generally slower than to the affective words. As a consequence, our priming scores may have overestimated response facilitation and/or underestimated interference in Experiment 4A. This explanation is in our view not very likely for two reasons: First, a close look at the pattern of reaction times in Experiment 4A shows that the difference to neutral words was caused by a processing advantage of positive words and not by a processing advantage of negative words. In fact, statistical analyses showed that the response speed to negative and neutral words was not different in any of the experiments. Second, and even more compelling, an analogous response facilitation effect was not observed in a control experiment in which the same words were categorized without associations to response outcomes (Experiment 4C). Although the assumption of neutral words functioning like a baseline should always be treated with caution, this objection is hence not plausible for baseline comparison with negative response cues.

The lack of corresponding response facilitation with pleasant action outcomes in the comparison of Experiment 4C with Experiment 4A was unexpected. It should be noted, however, that responses to positive words were generally emitted much faster than responses to negative and neutral cues. Thus, it is possible that a floor effect prevented a further RT reduction by a matching response-outcome association (for a related discussion see Kunde, 2001). Further research is necessary that examines this possibility.

The absence of a compatibility effect in Experiment 4B that lacked an acquisition phase prior to the test phase is instead in line with a two-stage model of action control claiming that previously learned action outcomes are retrieved from memory during the test phase. However, one may wonder why the recurrent production of response outcomes during the test phase was not sufficient for action-effect learning in Experiment 4B. In a comparison of different modes of action-effect learning, Herwig, Prinz and Waszak (2007) observed robust action-effect acquisition when the actions were selected endogenously (i.e., in a free-choice action mode); in contrast, no action-outcome learning was observed in several experiments when the actions were carried out in response to exogenous stimuli (i.e., in a forced-choice action mode). Even though subsequent research showed the action mode affects more the application than the acquisition of response-outcome associations (Pfister, Kiesel, & Hoffmann, 2011), a forced-choice action mode in the test phase explains why no stimulus-outcome compatibility effect was observed in Experiment 4B.

Experiment 5

A priming of unpleasant action consequences fits well with an additive model that expects an ideomotor effect irrespective of the value of the anticipated outcome: When responses become linked with pleasant and unpleasant outcomes, the activation of the affective outcome by an affective stimulus primes the associated response, producing an affective compatibility effect. According to this model, however, the affective valence of the associated response effect should also have a motivational effect on response selection: A response generating a pleasant outcome should be generally facilitated relative to the alternative response, which was not observed. Thus, while the present experiments provide clear support for a directive function of affective action consequences, they failed to demonstrate an incentive function so far.

One possible reason for the absence of an incentive effect is the nature of the test situation: When a response is enforced by fixed stimulus-response instructions, as in the test phases of our experiments, participants are motivationally prepared to generate unpleasant experiences with their responses according to the task instructions. Furthermore, the visual effects provided feedback on the correctness of a response, signaling the absence of an erroneous response. This feedback function may have reduced the unpleasantness of the negative response outcomes. **[5]** Thus, task configurations unique to forced-choice setups may have counteracted a motivational suppression of the response that generated an unpleasant effect, eliminating a motivational effect.

Experiment 5 examined this explanation by replacing the forced-choice test with a free-choice test. When response choice is free, participants can maximize pleasant experiences and minimize unpleasant experiences with their choices, making the value of the action outcome motivationally relevant for action selection (for a related argument see De Wit & Dickinson, 2009). Accordingly, the response key that generates a pleasant outcome should be pressed more frequently than the response key that generates an unpleasant outcome. In line with an additive model, we expected that such a motivational effect should emerge in addition to, and independently of, an ideomotor effect (i.e., an affective compatibility effect between response cues and response outcomes). Thus, participants should generally prefer responses associated with pleasant outcomes over responses associated with unpleasant consequences (indexing a motivational effect). This response bias should be additionally enhanced in the presence of positive stimuli but decreased in the presence of negative stimuli (indexing an ideomotor effect).

Method

Participants

Ninety-two volunteers (64 women) with an age between 19 and 38 years (M = 22.8, SD = 3.3) participated in exchange for payment or for partial course credit. Seven participants were left-handers. None had participated in the previous experiments.

Data sets of five participants were removed because of an insufficient response practice (i.e., fewer than 25% presses of one key) in the acquisition phase. Three other participants were excluded because they pressed only a single key in the test phase. In total, data sets of 84 participants were analyzed; 46 participants were randomly assigned to a condition in which the responses still produced outcomes in the test phase; 38 participants were assigned to the extinction condition.

Apparatus, Stimuli, and Procedure

Apparatus and stimuli were the same as in Experiment 3. In the test phase, participants could now freely decide between a left and right key press; however, a Go/Nogo-task was introduced to prevent participants from making a response choice before a stimulus had appeared (cf. Elsner & Hommel, 2001, Experiment 3). Depending on the content of a picture that was shown on the screen, task instructions were to withhold a response (no-go trial) or to choose between a press of the left or the right key without time pressure (go trial). Half of the participants in each test condition were instructed to withhold a response when the picture showed an animal and to press a key when the picture displayed a person; the other participant group received the opposite instructions. For the free response choice, it was emphasized that they could choose either key just like before in the acquisition phase but this time without minding a balanced response ratio. However, it was also pointed out that exclusively pressing a single button is not acceptable. Participants worked through 192 test trials, half of them were go-trials and the other half were no-go trials. List construction ensured that there were no more than three go-trials or no-go trials in a row. Erroneous trials were not repeated at the end of the test phase. Furthermore, the rectangle was now displayed for 300 ms in the acquisition phase. In all other details, the procedure was the same as that of Experiment 3.

Results

Acquisition Phase

Trials with response omissions (1.7% of all trials) and anticipatory responses (6.0% of all trials) were excluded. A mixed ANOVA of the response proportion with the factors “response key” (key assigned to the dominant vs. the non-dominant hand) and “outcome assignment” (pleasant outcome to the dominant hand vs. to the non-dominant hand) showed that participants pressed the key assigned to the dominant hand more frequently (M = 51%) than the key assigned to the non-dominant hand, $F(1, 82) = 10.14$, $p < .05$. This response preference tended to be more pronounced when the key assigned to the dominant hand produced a pleasant picture, $F(1, 82) = 2.82$, $p = .10$. Pleasant pictures were however not produced more often than unpleasant pictures (ΔM = 0.7%), $t(83) = 1.54$, $p = .13$.

Test Phase

Participants pressed a key in 2.5% (SD = 2.7%) of the no-go trials. Trials with response omissions (2.2% of all trials) and anticipatory responses (1.4% of all trials) were dropped from the analyses. The proportion of the responses was calculated for each participant as a function of the valence of the go-stimulus and the valence of the associated response outcome.

Response Choice. A mixed ANOVA with response cue, response outcome, and extinction test as factors yielded a main effect of response outcome and a significant interaction between response cue and response outcome. As shown in Figure 3, participants preferred the key that was associated with a pleasant outcome (M = 53%), $F(1, 82) = 5.54$, $p < .05$, irrespective of whether the key still produced an outcome in the test phase or not ($F < 1$). Furthermore, a response key was selected more frequently when the associated outcome was affectively consistent with the response cue, $F(1, 82) = 7.02$, $p < .05$. When a positive picture was presented as response cue, participants pressed the key associated with a positive outcome more frequently (M = 55%) than the key that generated a negative outcome, whereas no response preference was observed when a negative response cue was presented (Ms = 50%). Notably, this pattern of results was not affected by extinction condition ($F < 1$), suggesting a similar preference for affectively congruent response choices in both conditions.

A corresponding item-analysis corroborated these results. Responses associated with pleasant outcomes were emitted more often than responses associated with unpleasant outcomes, $F(1, 188) = 13.93$, $p < .001$. This motivational effect was increased by positive response cues relative to negative response cues, $F(1, 188) = 19.66$, $p < .001$. Extinction did not moderate these effects (with ps > .14).

Reaction Times. In an analogous analysis of the response times only the main effect of the valence of the response cue was significant, $F(1, 82) = 24.60$, $p < .001$. Responses were about 12 ms faster when a positive picture was presented as a go-stimulus. Furthermore, response times were not different for the keys associated with a pleasant outcome (M = 359 ms) and an unpleasant outcome (M = 358 ms), and the reaction time was about equal in compatible and incompatible trials (with both Fs < 1).

Contingency Awareness. In the post-experimental questionnaire, half of the 84 participants indicated knowledge of the correct R-O contingency. The ratio of aware participants did not differ between the conditions with and without response outcomes in the test phase (57% and 42%), $\chi^2(1, N = 84) = 1.73$, $p = .19$. In an ANOVA of the response proportion with contingency awareness as additional factor, the preference for the response associated with a pleasant outcome was not affected by contingency awareness ($F < 1$). However, the affective compatibility effect was affected by this factor, $F(1, 80) = 4.31$, $p < .05$. Aware participants preferred affectively consistent responses more than participants who were unaware of the R-O relationship, irrespective of whether the keys still produced effects in the test or not ($F < 1$). Follow-up comparisons in each subgroup revealed that the preference for affectively consistent choices was reliable when participants were aware of the R-O contingency ($\Delta M = 9.3\%$; $p < .01$) but not when they were unaware of the contingency ($\Delta M = 1.3\%$). Thus, explicit knowledge about the relationship between the responses and their affective effects moderated the preference for affectively congruent choices.

For a further exploration of the moderation by contingency awareness, we screened the difference scores between affectively consistent and inconsistent choices for outliers that might index a strategic use of the R-O contingency rules in the free choice test. Two participants, both of them being aware of the R-O contingency, produced a compatibility effect that was more than three interquartile ranges above the third quartile of the effect distribution, which is considered as an extreme outlier according to Tukey (1977). After exclusion of these participants, a preference for affectively consistent response choices was still reliable, $F(1, 80) = 6.12$, $p < .05$; notably, this effect was no longer influenced by contingency awareness, $F(1, 80) = 2.03$, $p > .10$, suggesting that the moderation by contingency awareness in the overall analysis was due to an extreme response bias in a small subset of “aware” participants. The statistical power to detect a large effect with this sample ($N = 82$) was sufficient ($f = 0.40$; $p = .95$); however, the probabilities to detect medium ($f = 0.25$; $p = .61$) and small effects ($f = 0.10$; $p = .15$) were not sufficient according to a post-hoc power analysis. Thus, it cannot be ruled out that contingency awareness had a subtle influence on the response choice that was not detected with the present experiment (but see also Footnote 4 on the expectation of a large mediating effect).

Discussion

Experiment 5 examined whether the hedonic implication of an action consequence has a motivational effect on response selection when participants have control over the action outcomes in a free-choice test situation. The results confirm this expectation. Participants pressed the key that generated a pleasant outcome more frequently than the key that produced an unpleasant outcome. Notably, this response bias was not mediated by the actual delivery of the outcomes in the test, nor by explicit knowledge of the contingency between the responses and their consequence. This suggests that the hedonic response bias was not based on a conscious strategy to maximize pleasant experiences.

In addition to a motivational effect, an affective compatibility effect was observed in response choices, which is analogous with the ideomotor effect observed in the reaction times of the previous experiments. Affective response cues primed responses with a corresponding outcome valence, independently of whether this outcome was pleasant or not. As a result, the hedonic response bias was enhanced when a positive response cue was presented but offset when a negative response cue was used, which is in line with the idea that motivational and ideomotor processes can have additive effects on action control.

Notably, the affective compatibility effect in the response choice was not affected by the extinction treatment. This finding is striking given that our previous experiments did not show a compatibility effect in the RT measure when response outcomes were not delivered during the test. The result is however in line with a study on ideomotor effects showing that learned response outcomes are retrieved in a free-choice test condition more efficiently than in a forced choice test condition (Pfister et al., 2011). The use of a free choice test (and the adoption of an intention-based action control mode during this test) hence explains why the ideomotor effect was more robust to extinction in this experiment.

Allowing a free choice between different responses is of course likely to invite more strategic processes that may alternatively explain the observed effects. Although the present data cannot rule out this argument completely, an exclusive account with response strategies is in our view not plausible for several reasons:

First, the response choices were closely balanced in the test phase. Given that a balanced ratio of response choices was instructed for the first (acquisition) phase of the experiment, participants may still have tried to produce equal frequencies of both responses during the test phase despite a change of the task instructions. If anything, a carry-over of a response strategy from the acquisition phase may thus have worked against motivational and ideomotor effects in the test phase, explaining (among other reasons) why these effects were not very pronounced.

Second, response strategies must have been very complex in order to completely account for the observed response pattern. For an account of the motivational effect, a simple strategy may have been to press the key associated with pleasant outcomes more often than the key associated with unpleasant outcomes. However, for an account of the compatibility effect, this strategy must have been pursued only when a positive response cue appeared on the screen and not when a negative response cue was presented on the screen. Furthermore, participants may also have attempted to keep the frequencies of both responses balanced during the test phase (see the point above). Even though such a complex mixture of response strategies is not impossible, it is in our view very unlikely that our participants entertained such complex strategies without any additional incentives to produce the expected results.

Third, a strategic production of response outcomes requires knowledge of the relationship between the responses and associated outcomes. Contingency knowledge (as indexed by our postexperimental questionnaire) had only a weak influence on the observed effects. As a matter of fact, contingency awareness had no effect on the size of the motivational effect, and a significant compatibility effect was obtained even after the removal of two extreme outliers that produced compatibility effects with a size of 90% and more. This huge deviation from the rest of the sample (M = 3%, SD = 12.1) suggests that response strategies should produce much stronger effects than were observed in the data.

General Discussion

Ideomotor theory proposes that actions are represented by their sensory effects, and that the anticipation of the sensory effect by itself is sufficient to trigger the behavioral action. The present experiments examined whether this theory can also be extended to affective consequences of actions, and whether anticipations of affective action outcomes influence action control differently than anticipations of non-affective, sensory action effects.

In line with ideomotor theory, five experiments provided clear evidence that action selection is influenced by the compatibility relation between affective response cues and the affective consequences of responses. A response was generated faster (in a forced-choice test) and more frequently (in a free-choice test) when the produced outcome was affectively consistent with a response cue than when their affective values were inconsistent. This compatibility effect is in line with an extended version of ideomotor theory proposing that an affective action consequence becomes associated with the producing movement, and that activation of the affective consequence by an affective stimulus primes the associated response. Furthermore, a compatibility effect was obtained even though many different visual stimuli were used to induce a positive or negative action outcome. In contrast to the previous study of Beckers et al. (2002), the present experiments thus conclusively rule out the possibility that only sensory properties of action outcomes were learned in an acquisition phase that were later evaluated "online" when being retrieved in the second phase. Rather, our findings suggest that the positive or negative consequence itself is integrated into the cognitive action representation, so that when the representation of the response is accessed during action planning, the affective consequence is reactivated as well. **[6]**

Notably, affective action outcomes influenced response selection without a corresponding task instruction to produce affective outcomes and without explicit knowledge of the relationship between the responses and their consequences. Furthermore, the valence of the response cues and response outcome was completely irrelevant for the task at hand. In combination, these findings support a strong version of the two stage model of action-effect learning claiming that (a) representations of affective outcomes become automatically associated with the representation of responses that produced these outcomes, and that (b) these representations are automatically retrieved in the course of initiating a response, even when they are not useful for the task at hand.

An affective compatibility effect between stimuli and response outcomes was however observed only when the responses still produced outcomes in the test phase, but not in an extinction test. Even though the extinction of an instrumental response is a standard finding in conditioning research (Bouton, 1994), once they were acquired, a retrieval of sensory action-effects (e.g., high and low tones) has been found to be remarkably resistant to extinction procedures. **[7]** In fact, some studies observed a sustained influence of sensory effects on response selection even with hundred extinction trials and more (e.g., Elsner & Hommel, 2001). These different findings suggest that associations to affective action consequences are less robust to extinction than associations to non-affective, sensory effects.

One possible explanation of a facilitated extinction of affective action outcomes is that the extinction treatment elicited an opposite affective reaction in the individual. More specifically, the unannounced non-delivery of a pleasant outcome in the test phase may have produced a negative feeling of disappointment, whereas the non-delivery of an expected unpleasant outcome elicited a positive feeling of relief (Crosbie, 1998; Papini & Dudley, 1997). These feelings of disappointment and relief are contrary to and in conflict with the original affective experiences elicited in the acquisition phase, facilitating their extinction. An alternative possibility is that differences in task procedures are responsible for a more rapid extinction. For instance, studies of action-effect learning in the sensory domain have typically presented only two auditory stimuli as response effects that are arguably more salient than the complex visual stimuli that were displayed in the present experiments. Furthermore, the response effects became task-relevant in these studies when the auditory effects were presented as response cues in the test phase. In combination, these task procedures may have strengthened the acquisition of the response effects and/or their retrieval in the test phase (see Dutzi & Hommel, 2009; Flach, Osman, Dickinson, & Heyes, 2006; Ziessler, Nattkemper, & Frensch, 2004), which would explain an enhanced resistance to extinction. More research is necessary to decide between these explanations.

Importantly, an ideomotor (compatibility) effect was also observed with responses that generated an unpleasant effect (Experiment 4A). This finding is important because it contradicts the assumption that only positive action outcomes are effective in producing the associated motor pattern, while negative action outcomes are not (gatekeeper model); instead, this finding suggests that affective sensations can guide action selection as anticipated consequences, even when they have aversive properties.

A directive function of aversive action consequences is in line with research showing that electric shocks facilitate skill learning when they follow reliably after a correct response (e.g., Holz & Azrin, 1961; Muenzinger, 1934; Tolman, Hall, & Bretnall, 1932). In a classic study, Nelson, Reid, and Travers (1965) provided children feedback about the correctness of a response by the use of a verbal response (right or wrong), by a neutral sound, or by the use of an electric shock. Results showed that the electric shock was just as effective for learning as the other feedback modes, even when the shock was contingent upon the execution of a correct response. When people are highly motivated to learn a skill, learning to behave in a correct way thus appears to depend much more on the information an action effect provides about the behavior to be acquired than it does on how the action effect makes one feel.

The implication of this approach is that the cognitive anticipation of an unpleasant event, once learned as a behavioral effect, can prime the associated behavior that generates this event. It is clear that this priming process is highly dysfunctional for a behavior control system that aims at an avoidance of unpleasant consequences (Eder & Hommel, 2013). For a motivational control of behavior, ideomotor action must thus be constrained by a second process that is sensitive to the needs and desires of the person. In the present study, such a motivational process was observed when a free-choice test was used instead of a forced-choice test. In this test situation, pleasant action consequences were produced more frequently than unpleasant consequences. Thus, the possibility to avoid unpleasant outcomes may explain (among other reasons) why a motivational effect was observed with a free-choice test but not in a forced choice test. However, it should be also noted that Beckers and colleagues (2002) obtained some evidence for a motivational effect in a forced-choice task when an electric shock was delivered as aversive outcome. Thus, the hedonic value of an action effect may be able to affect instructed responses as well when the affective consequence is sufficiently intense.

The present findings support a model that proposes additive but independent effects of affective and sensory properties of outcomes. When an action consequence is activated in memory, codes representing the sensory properties and codes representing the affective value of the outcome are activated simultaneously. Activation of the sensory codes then triggers an ideomotor process, while activation of the affective codes triggers a motivational process. As a result, the behavioral impulse induced by the ideomotor processes is potentiated by the motivational process when the anticipated outcome is positive, while the impulse is suppressed when the anticipated outcome is negative.

Interestingly, a very similar distinction between sensory and affective features of outcome representations was discussed in research on Pavlovian-to-instrumental transfer of control (PIT; Trapold & Overmier, 1972). In a typical demonstration of outcome-specific PIT, Pavlovian relations between stimuli and differential outcomes (S1-O1, S2-O2) and instrumental relations between responses and outcomes (R1-O1, R2-O2) are first established in separate learning sessions. In a transfer test, both responses are then made available in extinction, and the preference for a specific response is measured in the presence of each conditioned stimulus (i.e., S1: R1 vs. R2; S2: R1 vs. R2). The typical result is a preference for the response whose outcome is signaled by the Pavlovian cue (Urcuioli, 2005). For instance, when lever pressing was reinforced with sucrose and chain pulling with pellets, rats press the lever when sucrose is cued by an accompanying stimulus, whereas they pull the chain when the Pavlovian cue signals the availability of pellets (Colwill & Rescorla, 1988). Given that both reinforcers are rewarding to the same degree, it seems that the activation of a sensory representation by a Pavlovian cue can excite the response that is associated with this outcome – a response tendency that fits nicely with ideomotor theory. Furthermore, at least one human study found that devaluation of a monetary rewards after training eliminates outcome-specific PIT (Allman, DeLeon, Cataldo, Holland, & Johnston, 2010; but see also Hogarth & Chase, 2011, who failed to find an analogous effect with drug-related outcomes). That means, the Pavlovian cue lost its capacity to excite a response that earned the same outcome when the outcome acquired a negative value. This latter finding fits with the idea of a motivational process that suppresses behavioral impulses induced by an ideomotor process.

According to the present model, motivational processes leak into a second stage of action control by influencing the activation strength of associated motor codes. Notably, these codes may not be the only target of motivational processes. In line with a common-coding approach to perception and action, activation from an affective code or tag should spread not only to motor codes but also to perceptual codes (Eder & Klauer, 2009). Accordingly, affective codes should influence the perception of associated stimuli as well. In line with this hypothesis, Raymond and O’Brien (2009) showed that stimuli associated with rewards are detected more easily than stimuli associated with punishments when attention is limited and when the motivational relevance of rewards and punishments is comparable for the task at hand. Thus, an integration of a positive outcome appears to enhance the accessibility of associated perceptual codes. Furthermore, motivationally relevant action effects are perhaps acquired more effectively than motivationally irrelevant outcomes. In a recent study on action-effect acquisition, sensory action effects signaled a monetary reward or they were unrelated to a reward (Muhle-Karbe & Krebs, 2012). When the sensory effect signaled a reward during the acquisition phase, the sensory effect primed the associated response when it was presented as a response cue in a subsequent test phase (exhibiting an ideomotor effect); however, no response priming was observed when the action effect was unrelated to a reward. Thus, a motivational salience of action effects appears to enhance their acquisition, suggesting that several stages of action control are affected by motivational processes.

Conclusions

To conclude, the present findings show that affective action effects have directive and incentive functions for action control. As anticipated sensory consequences, they can be used to select and initiate a behavior that produces the anticipated effect, even when the outcome has aversive properties. This ideomotor process allows for a volitional control of action. As anticipated hedonic consequences, they can be used to selectively enhance behaviors that generate pleasant and desired effects, allowing for a motivational control of behavior that is in the service of the individual’s needs and desires. The outcome is a dynamic action regulation in which behavioral tendencies evoked by ideomotor and motivational processes mutually support or constrain each other in the control of instrumental action.

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FOOTNOTES

1 This timing of the response was introduced in order to prepare the participant for the test phase in which instructions were to respond not before the response cue has disappeared from the screen.

2 Note that the probability of a lucky guess was p = .25 (i.e., one out of four possible R-O combinations). Thus, knowledge of the R-O contingency was above chance but far from perfect, which is not too surprising given that the affective outcomes in the present experiments were subtle and task irrelevant.

3 Statistical power was however insufficient to detect a small effect (f = 0.10; p = .21). Thus, our experiments cannot rule out the possibility that a weak influence of contingency awareness was not detected. Note, however, that the assumption of a small effect is unwarranted if it is assumed that contingency awareness mediates the learning-effect in an all-or-none fashion.

4 Unfortunately, the number of correct responses during task practice was too low for a meaningful analysis (about 33% of the responses in these trials were incorrect).

5 Emotion research has shown that viewing unpleasant IAPS-pictures prompts defensive activation even when these pictures signal safety from a painful shock (Bradley, Moulder, & Lang, 2005). Given this evidence, it is unlikely that feedback of a correct response can completely override the intrinsic unpleasantness of these stimuli.

6 A reactivation of learned affective action consequences fits well with Damasio's (1994) concept of a "somatic marker" that provides a gut feeling on the merits of a given response.

7 It should be noted that the extinction of a behavioral response does not necessarily imply an extinction of the underlying associative structure that governs the instrumental response. In fact, there is strong evidence that a response-outcome association is preserved even when the overt response is not displayed anymore in an extinction test (Rescorla, 1993; see also a reinstatement of extinguished fear responses in human aversive conditioning; Hermans, Dirikx, Vansteenwegen, Baeyens, Van den Bergh, & Eelen, 2005).

Table 1

Reaction times (in ms) and error rates (in percent) as a function of the valence of the stimulus (S) and the response outcome and affective compatibility effects in the conditions with and without outcome (O) presentation in the test phase. Standard deviation in parentheses.

		Pleasant Response Outcome				Unpleasant Response Outcome				Affective Compatibility Effect			
		With O in Test		Without O in Test		With O in Test		Without O in Test		With O in Test		Without O in Test	
		RT	Error	RT	Error	RT	Error	RT	Error	RT	Error	RT	Error
Exp 1	S+	620 (69)	9.6 (7.4)	608 (70)	7.7 (7.3)	636 (67)	6.5 (4.8)	605 (77)	5.7 (6.2)	15* (26)	-1.6 (5.6)	5 (19)	-1.5 (5.7)
	S-	637 (77)	8.2 (6.9)	621 (77)	6.7 (5.2)	623 (70)	8.4 (7.7)	608 (77)	7.7 (6.8)				
Exp 2	S+	610 (46)	6.9 (6.0)	618 (63)	6.9 (7.8)	630 (58)	9.5 (7.9)	618 (64)	7.4 (7.9)	9* (19)	1.7 (4.9)	-5 (14)	0.1 (4.8)
	S-	630 (53)	7.3 (6.7)	626 (63)	7.5 (8.2)	630 (67)	6.6 (6.7)	636 (74)	7.8 (6.5)				
Exp 3	S+	514 (95)	6.7 (6.3)	472 (48)	7.3 (5.9)	518 (96)	11.4 (8.4)	470 (39)	7.5 (5.4)	11* (29)	2.9* (4.9)	-7 (23)	-0.1 (4.6)
	S-	535 (103)	9.5 (5.2)	478 (48)	6.1 (4.6)	518 (91)	8.4 (7.8)	491 (48)	6.5 (7.2)				
Exp 4A	S+	630 (58)	6.8 (7.2)	n/a	n/a	640 (78)	10.5 (9.1)	n/a	n/a	13* (31)	2.6* (7.7)	n/a	n/a
	S-	667 (66)	13.8 (9.6)	n/a	n/a	650 (66)	12.4 (8.2)	n/a	n/a				
	Sn	663 (73)	8.1 (9.0)	n/a	n/a	667 (69)	8.4 (8.7)	n/a	n/a				
Exp 4B	S+	653 (85)	6.1 (5.2)	n/a	n/a	654 (76)	8.1 (7.2)	n/a	n/a	1 (34)	0.7 (5.1)	n/a	n/a
	S-	682 (83)	10.3 (8.3)	n/a	n/a	682 (79)	10.8 (7.2)	n/a	n/a				
	Sn	697 (84)	7.6 (7.6)	n/a	n/a	690 (86)	7.4 (7.6)	n/a	n/a				

* $p < .05$. Level at which mean is different from zero.

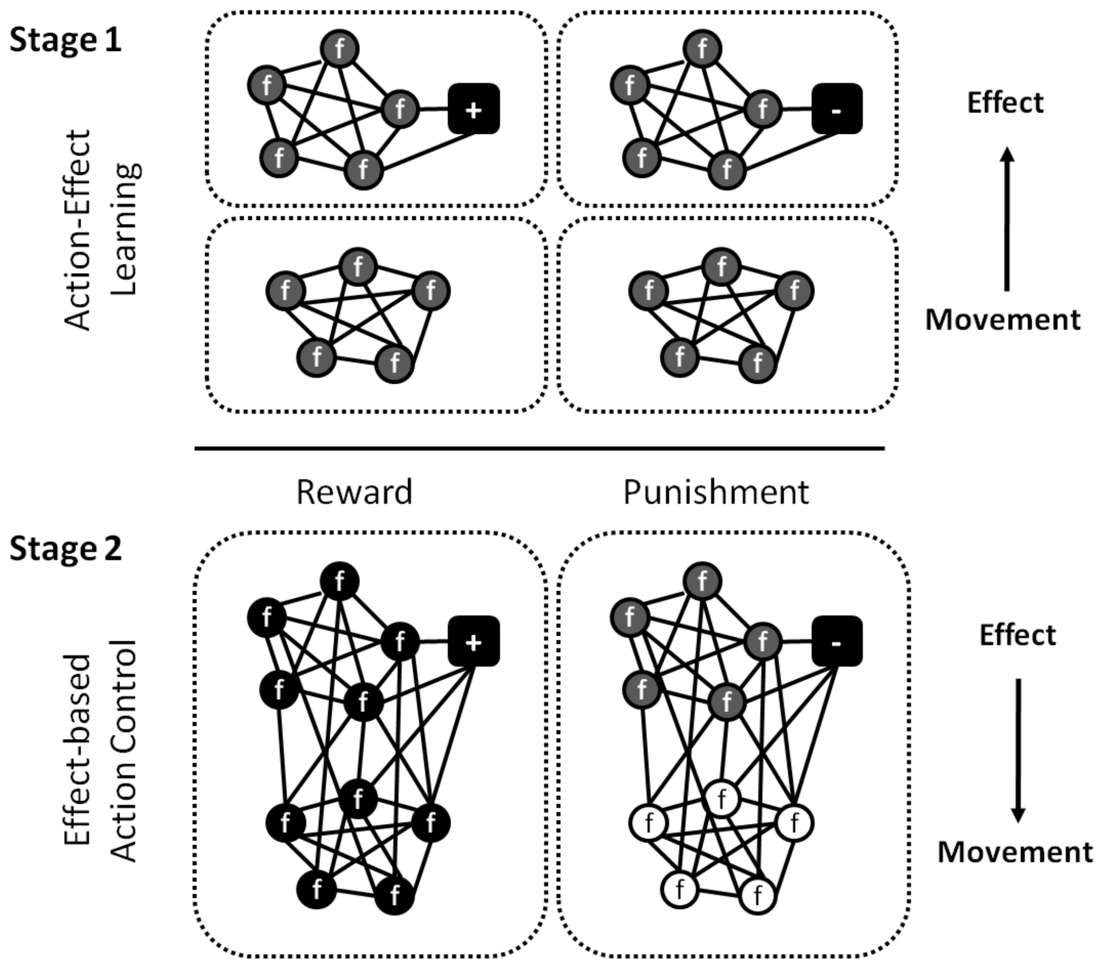
Note. Affective compatibility effects were computed by subtracting the response times (error rates) in trials with affectively consistent S-O combinations from the response times (error rates) in trials with affectively inconsistent S-O presentations.

FIGURE CAPTIONS

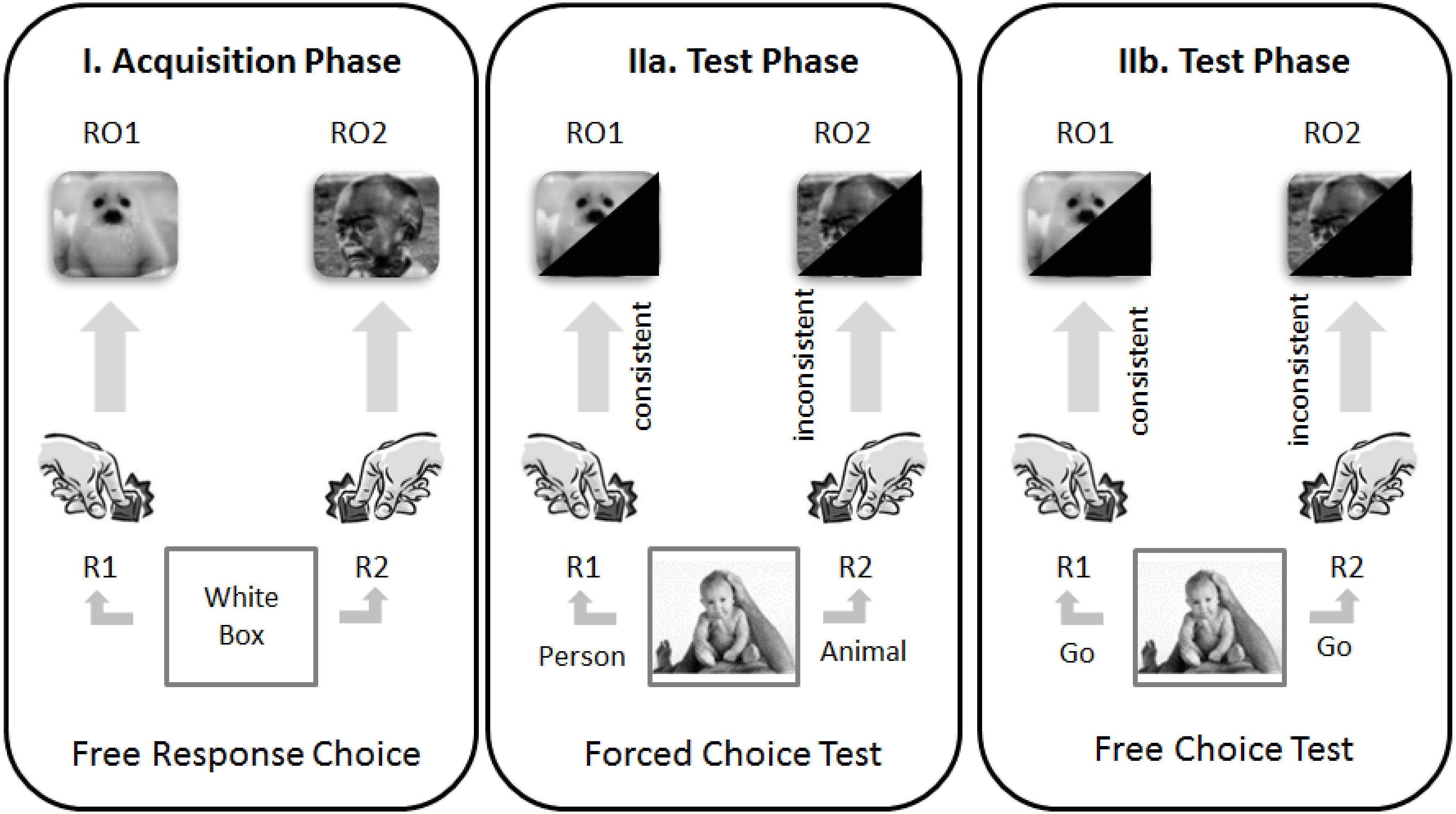
Figure 1. Two-stage model of the emergence of affective movement control. At Stage 1, codes representing the features of a movement become automatically associated with codes representing features of the produced effect, including the affective value of the outcome. At Stage 2, the motor pattern is selected by activating the codes that represent its expected effect. Spread of activation is potentiated by affective codes that represent a positive outcome value (reward) but suppressed by codes that encode a negative outcome value (punishment). As a consequence, ideomotor action is suppressed (light circles) during the anticipation of a negative outcome and enhanced during the anticipation of a positive outcome (dark circles).

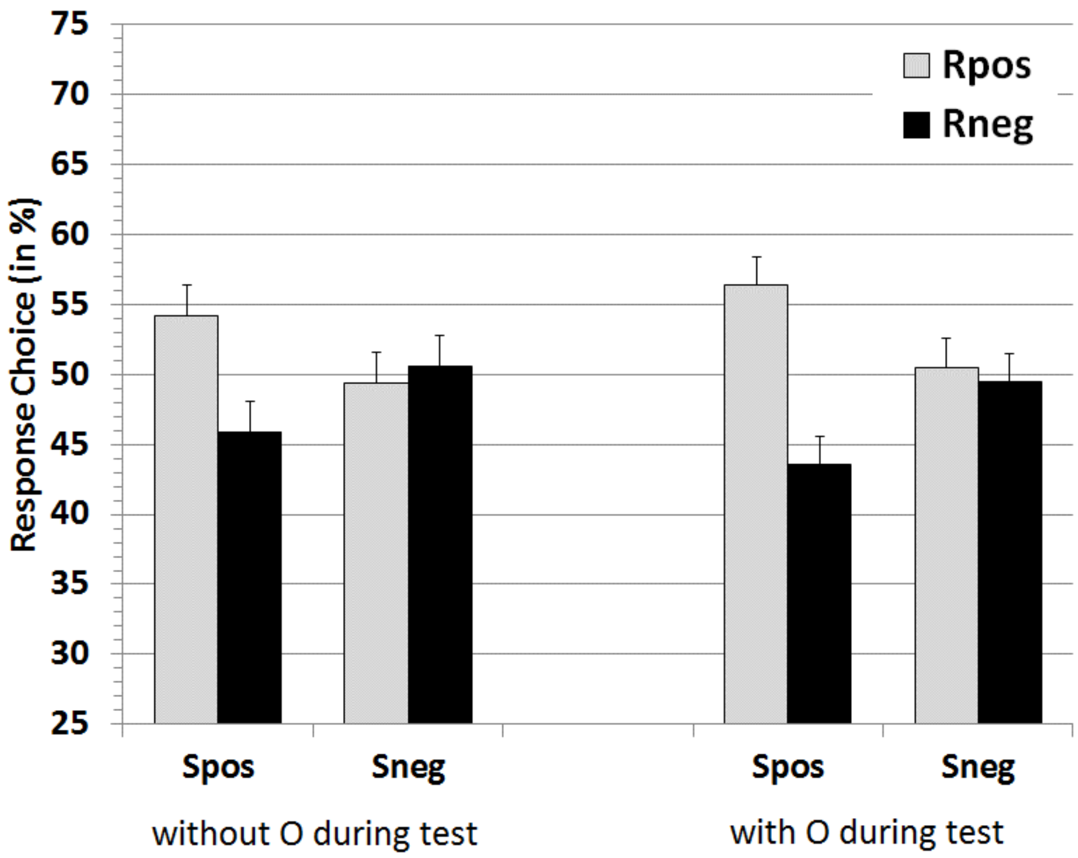
Figure 2. Overview of basic experimental procedures. In a first acquisition phase, left and right button presses (R1 and R2) consistently produced either pleasant or unpleasant visual outcomes on a computer screen (counterbalanced as RO1 and RO2). In a subsequent test phase, the response buttons were pressed in response to a neutral feature of affective stimuli either in a speeded forced choice test (according to instructed S-R mapping rules; middle panel) or in a free choice test (according to Go/No-Go instructions; right panel). Response associations with positive and negative outcomes during the test were consistent or inconsistent with the valence of the test stimulus reacted to. Button presses discontinued to produce visual outcomes in some test conditions (extinction tests). Experiments differed in respect to whether affective pictures or affective words were presented as response outcomes and/or as test stimuli (see the text for further details).

Figure 3. Response choices in Experiment 5 as a function of a positive or negative valence of the stimulus (S) and the response (R) in the conditions with and without continued outcome (O) presentations during the test phase. Error bars show the standard error.



Stage 1
Action-Effect Learning
Effect
Movement
Reward
Punishment
Stage 2
Effect-based Action Control
Effect
Movement


I. Acquisition Phase
RO1
RO2
R1
White Box
R2
Free Response Choice
IIa. Test Phase
RO1
RO2
consistent
inconsistent
R1
Person
R2
Animal
Forced Choice Test
IIb. Test Phase
RO1
RO2
consistent
inconsistent
R1
Go
R2
Go
Free Choice Test



75
70
65
60
55
50
45
40
35
30
25
Response Choice (in %)
Rpos
Rneg
Spos
Sneg
Spos
Sneg
without O during test
with O during test