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Attracted by Rewards: Disentangling the Motivational Influence of Rewarding and Punishing Targets and Distractors

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Traditional research on action control focuses on the outcome of a decision process and neglects the way by which these decisions are put into action. Here, we provide direct evidence for ongoing control of motivational impulses during postdecision action execution. Using a movement task in which gain/loss stimuli either functioned as targets or distractors, we show that different phases of a movement are distinctly shaped by motivational impulses. Response initiation times revealed control costs for loss targets and distractors, and control benefits for gain targets. However, movement trajectories revealed strong attraction toward the gain distractor, in line with a hypothesized pull of approach-related stimuli, while targets and distractors associated with losses had no repulsive avoidance-related effect on movement trajectories. These results show that motivational processing of goal-relevant stimuli influences the way in which goal-directed actions are executed and highlight a prominent role of reward-related distractors in shaping movement execution.

Keywords: impulsive behavior, movement trajectories, motivational conflict, approach-avoidance motivation, action execution

Every now and then, a stimulus in the environment signals the opportunity to achieve a desired outcome. This can be a rewarding and beneficial if the potential outcome is in line with our goals. However, in everyday life people regularly experience situations in which internal goals conflict with external stimuli that afford strong motivational impulses (Lewin, 1935; Hofmann, Kotabe, & Luhmann, 2013). Resolving this motivational conflict requires a control mechanism that shields the current goal against distractors. Typically, research investigated the control of motivational conflict by assessing how much time participants need to arrive at a decision and whether the outcome of this decision process is in line with the actor's original goals. It is less clear how motivational conflict affects goal-directed movements that are performed subsequently to this decision.

To fill this gap, this article focuses on how control processes shape action initiation and execution (in the tradition of Hovland & Sears, 1938). Critically, we make the case that appetitive and aversive stimuli affect movement initiation and execution differently depending on whether they are presented as targets or distractors. For this aim, we used continuous recordings of finger movements on a tablet computer for a direct measure of spatial attraction/repulsion by appetitive/aversive stimuli. Thus, the present research suggests a novel look on the control of motivational response tendencies by analysis of movement trajectories in the

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presence of motivationally relevant targets and distractors.

Conflict Between Different Motivational Orientations

In motivation research, two fundamental action inclinations are typically distinguished: those that dispose the organism to approach, attachment, and consumption, and those that prepare the individual for avoidance, escape, and defense (Elliot, 2008; Lang, Bradley, & Cuthbert, 1990). Approach behavior is motivated by the prospect of pleasure, satisfaction, and rewards, while avoidance behavior is motivated by the prospect of displeasure, losses, and punishments (Eder & Hommel, 2013). Following the pioneering work of Kurt Lewin (1935), motivation scientists studied different types of motivational conflicts involving urges to approach, to avoid, or both. In this research, it is typically assumed that a capacity for control can resolve motivational conflict by replacing the impulsive tendency with an alternative action that is in the service of the prioritized goal (Strack & Deutsch, 2004).

Replacing an unwanted action tendency with the intended one is typically error-prone and requires time. Traditional research on control has therefore focused on the outcome of a decision process or the time needed to arrive at a decision. Failure to select an action corresponding with the prioritized goal or increased decision times is taken as an index of conflict (e.g., Inzlicht & Gutsell, 2007). In line with classic stage models of information processing (e.g., Sternberg, 1969), the execution of an intended action is viewed as being only the final output of a cognitive processing chain that proceeds encapsulated from preceding cognitive operations (Song & Nakayama, 2009). Accordingly, the question how decisions and associated control processes are enacted has received little attention (Rosenbaum, 2005). However, substantial evidence from different areas in psychology suggests that cognitive operations affect not only the duration of the planning process but also the way in which the goal-directed movement is executed (e.g., Buetti, Juan, Rinck, & Kerzel, 2012; Freeman & Ambady, 2014; Pfister, Janczyk, Wirth, Dignath, & Kunde, 2014; Pfister, Wirth, Schwarz, Steinhauser, & Kunde, 2016; Spivey, Grosjean, & Knoblich, 2005; Wirth, Pfister, Janczyk, & Kunde, 2015).

Extending this line of research to motivational conflicts, temporal and spatial parameters of motor execution have been shown to reveal important information about control operations (Dignath, Pfister, Eder, Kiesel, & Kunde, 2014). Participants in this study were instructed by a cue to move a mouse cursor (showing a little manikin) as quickly as possible from a start area to a target areas positioned on the left and right upper parts of the computer screen. One target area procured a small reward (gain target: +5 points), while the other target location inflicted a small loss (loss target: −5 points). Both areas were visible on the screen in each trial, and a cue indicated whether the mouse cursor had to be moved to the location procuring a gain or to the location inflicting a small loss. Movements to the incorrect side resulted in an even greater loss (−10 points) than a successful movement to the loss target. Analysis of the mouse movement revealed that movement trajectories toward loss targets deviated away from the designated target toward the alternative location associated with gain, although participants ultimately executed the correct action. Thus, spatial parameters of movement execution were indeed sensitive to motivational conflicts.

However, the study was inconclusive regarding the nature of the motivational conflict. As described above, two different types of motivational inclinations could have contributed to the effect: (a) a motivational impulse to avoid loss might have deflected the trajectory away from the loss target, or (b) a motivational impulse to approach the gain distractor might have attracted the trajectory toward the gain distractor. A third possibility is that both action inclinations affected the movement trajectory simultaneously.

The Present Research

The aim of the present research was to disentangle appetitive and aversive action tendencies in the motivational conflict situation described above. Three experiments tested whether targets and distractors associated with gains and losses trigger motivational tendencies that affect movement trajectories. For a separate assessment of approach and avoidance tendencies, we presented neutral targets and distractors. In each trial, participants saw a motivational target and a neutral distractor, or a neutral target and a motivational distractor. Additional trials with neutral targets and neutral distractors served as a baseline measure for comparison. In three experiments, we recorded trajectories of continuous finger movements on a computer tablet (for a similar design, see Wirth, Pfister, & Kunde, 2016; Wirth, Pfister, Foerster, Huestegge, & Kunde, 2016) to assess the impact of approach and avoidance-related impulses on movement control.

Experiment 1

Participants moved the index finger from a starting area at the bottom center to an upper-left or -right area on an iPad touchscreen (see Figure 1 for an illustration). A movement cue designated the target for each trial. Correct responses were always rewarded with 1 point. Reaching the gain target was rewarded with additional 5 points, while 5 points were subtracted from the total score when the loss target was approached. Movements to the neutral target yielded zero points. Incorrect responses to the distractors and responses that ended in neither of the designated target areas were punished with a subtraction of 10 points. Participants were informed that they would earn a candy bar if the final point score exceeded a particular (not further specified) threshold.

We analyzed three dependent variables: (1) Initiation time (IT) is the time it takes to move the finger out of the start area, measured from cue onset. (2) Movement time (MT) is the time of the actual movement execution (i.e., the time interval between leaving the start area and lifting the finger from the touchscreen). (3) Area under the curve (AUC) is defined as the area between the actual trajectory and a straight line from the point where the finger left the start box to the point where the finger was lifted from the screen. We conceptualized IT as a measure of action planning time, while MT and AUC measure temporal and spatial characteristics of action execution. We had the following hypotheses for the action planning and execution phases:

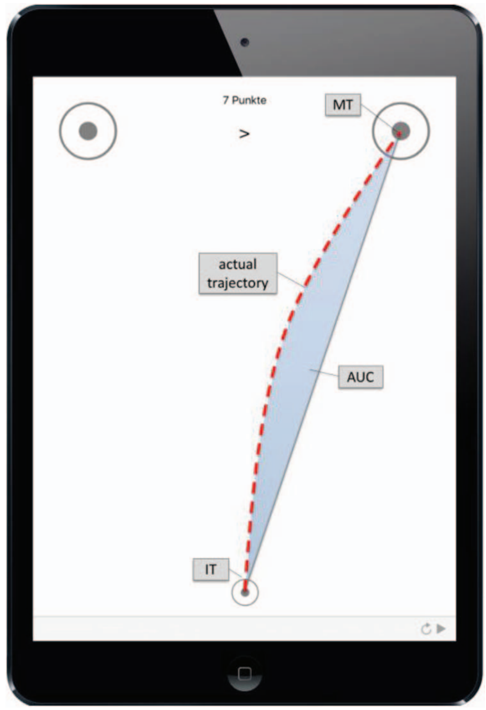

Figure 1. Movement task with relevant measures. Participants dragged their index finger in a continuous movement from the starting area at the bottom to one of the two areas at the upper corners of the screen. The target area was defined by an arrow (top center). Initiation time (IT) was defined as the time from target onset to movement initiation. Movement time (MT) was defined as the time of movement execution. Area under the curve (AUC) measures the area between the actual trajectory and a straight line from start- to endpoint. The total point score was displayed at the top center of the display. See the online article for the color version of this figure.

Action Planning

If the prospect of a gain promotes approach, this tendency should facilitate preparation of a corresponding action relative to a neutral baseline, while the threat of a loss should inhibit preparation of a corresponding action. Thus, ITs should be shorter for movements to the gain target and longer for movements to the loss target relative to a baseline (with neutral stimuli only). In contrast, automatic preparation of an approach response should interfere with preparation of a response to a neutral target (as is the case with gain distractors), while this planning is facilitated by automatic avoidance of a loss (with loss distractors). Thus, ITs for movements to neutral targets should be longer with gain distractors and shorter with loss distractors.

Action Execution

Similar to action planning, when moving toward a gain target, responses are expected to be more efficient (shorter MTs, smaller AUCs) because the motivational tendency to approach this area is congruent with the task-defined motor intention. In contrast, when moving toward a loss target, movements are expected to be less efficient (longer MTs, greater AUCs) because the task-defined goal of the response is in conflict with a motivational urge to avoid a loss. For movements to a neutral target, exactly the opposite pattern of motivational facilitation and interference was expected. If the prospect of a gain attracts corresponding movements (to a gain distractor), then MTs should be longer and AUCs should be increased because the movement trajectory is attracted away from the target toward the distractor. In contrast, distractors related to a loss should facilitate swipes to the neutral target (shorter MT, smaller AUCs), because the movement trajectory is pushed away from the distractor toward the correct target.

Method

Participants. Forty participants were recruited (mean age = 29.8 years, *SD* = 8.9, 20 male, 4 left-handed) and received €5 monetary compensation. All participants gave informed consent, were naïve to the purpose of the experiment, and were debriefed after the session. The data from three participants could not be analyzed due to insufficient data quality. Two participants were removed due to high error rates (>30%).

Apparatus and stimuli. The experiment was run on an iPad in portrait mode, which sampled the participants' finger movements at 100 Hz. Viewing distance was about 50 cm. The starting position for the movement (a circle of 1 cm in diameter) was located at the bottom center of the screen, 17 cm from the middle of the target and distractor positions at an angle of 31° to each side. The target and distractor areas were two circles of 2 cm in diameter in the upper-left and -right corners of the display in blue, yellow, or gray. They were separated by 11 cm (center to center). We used arrows to prompt movements to the left or to the right of these areas, and arrows were displayed in between the two areas at the top center of the screen (see Figure 1). The area that the arrow pointed toward was the target, while the other area was the distractor. Movements toward blue and yellow targets indicated a gain or loss trial pertaining to points that could be earned in the experiment (color-reward mapping was counterbalanced across participants), while gray targets indicated a neutral condition. Participants were instructed to accumulate as many points as possible, and the top center of the screen also housed the participant's score. Correct responses were always rewarded with 1 point (+1), movements to a gain target were additionally rewarded with a bonus of 5 points (+5), while movements to loss targets subtracted 5 points (−5) from the participant's account. Movements to a neutral target did not procure a bonus (+0). Points were credited after a correct response to the participant's score. Movements to the wrong target area (errors) or not hitting a target area at all (omissions) were punished with a loss of 10 points (−10). Participants were informed that they could exchange their points to candy if their score exceeded a certain (but not further specified) threshold at the end of the experiment. For the experimental trials, a gain or loss area was always accompanied by a neutral area, and either of the two areas could become the current target. This procedure resulted in two pairs of combinations: one pair in which the gain or loss area was the target (target/distractor combinations: Gain/Neutral and Loss/Neutral), and one pair in which the gain or loss area was the distractor (target/distractor combinations: Neutral/Gain and Neutral/Loss). As a fifth combination, we used trials with two neutral areas (Neutral/Neutral) for a baseline measure. Each combination was presented 10 times per block. Additionally, label trials with a combination of gain and loss areas (Gain/Loss, Loss/Gain) were presented. These were not instructed by arrows, but by a plus or minus sign. When a plus sign appeared, participants had to reach the gain area, while a minus sign prompted a movement to the loss area (for a similar procedure, see Eder & Rothermund, 2008). These trials served to strengthen the color-reward association during the experiment and were not included in the analyses reported below. Each label trial was randomly intermixed four times per block.

Procedure. Participants started each trial by touching the starting area with the index finger of the dominant hand. Simultaneously, two circles in the upper half of the screen appeared as possible target areas. After a dwell time of 200/300/400 ms (chosen randomly for each trial), an arrow (or a plus/minus sign) appeared that designated a movement to the left or the right area as target. The dwell time was jittered to avoid an automatic initiation of a response after a fixed time period. Participants were then to execute a smooth and continuous movement to the designated target area as quickly as possible. A trial ended when the finger was lifted from the touchscreen. Points for a correct response were rewarded and accumulated ("+1 +0" for neutral targets; "+1 +5" for gain targets; "+1 –5" for loss targets). In case of an incorrect response, 10 points were subtracted from the participant's account. Participants could decide when to start a trial and how long to pause between blocks. Overall, participants completed 10 blocks of 58 trials each.

Results

Preprocessing. We analyzed three variables of each movement: The time from stimulus onset to movement initiation (IT), the duration of the movement (MT), and the area between the actual trajectory and a straight line from start- to endpoint (AUC). IT was defined as the time that it takes for the finger to leave the starting area after the imperative stimulus (arrow, plus, or minus) was displayed. From this point, x and y coordinates were recorded; MT was determined when the finger left the touchscreen. AUC was computed from the time-normalized coordinate data of each trial by using custom MATLAB scripts (Mathworks, Inc.). Movements to the left were mirrored at the vertical midline for all analyses. AUC was computed as the signed area relative to a straight line from start- to endpoint of the movement (positive values indicating attraction toward the opposite side; negative values indicating attraction toward the nearest edge of the display).

Data selection and analyses. Participants gained 366 points on average ($SD = 177.4$). For the following analyses, we removed trials in which participants approached the wrong target area or failed to hit any of the target areas at all (4.8%). Trials were discarded as outliers if any measure (IT, MT, AUC) deviated more than 2.5 *SD*s from the respective cell mean (6.4%). The analyses comprised three steps for each measure. First, all experimental conditions were analyzed in a 5 × 3 analysis of variance (ANOVA) with condition (target/distractor combinations: Gain/Neutral, Loss/Neutral, Neutral/Gain, Neutral/Loss, Neutral/Neutral) and delay (0.2 s, 0.3 s, 0.4 s) as within-subject factors for omnibus tests. Then, each of the four conditions that included a motivationally relevant target area (Gain/Neutral, Loss/Neutral, Neutral/Gain, Neutral/Loss) was compared to the baseline condition (Neutral/Neutral). Finally, both conditions with motivational targets (Gain/Neutral, Loss/Neutral) and both conditions with motivational distractors (Neutral/Gain, Neutral/Loss) were compared against each other to test whether motivational targets and distractors affect movement control differently (see Figure 2 for an overview of the results).

Initiation times. A significant effect of condition, $F(4, 31) = 25.00$, $p < .001$, $\eta_p^2 = .76$, as well as a significant effect of delay, $F(2, 33) = 804.00$, $p < .001$, $\eta_p^2 = .98$, emerged, whereas the interaction between the two factors was not significant, $F(8, 27) = 1.41$, $p = .236$, $\eta_p^2 = .30$ (degrees of freedom relate to the multivariate approach to within-subjects ANOVA to avoid violations of sphericity). Trials with gain targets differed from the baseline, $t(34) = -5.15$, $p < .001$, $d = -0.87$, $\Delta = -18$ ms (with negative numbers indicating faster ITs than in the baseline condition), as did trials with a loss target, $t(34) = 2.45$, $p = .020$, $d = 0.41$, $\Delta = 8$ ms; trials with a gain distractor, $t(34) = 3.48$, $p = .001$, $d = 0.59$, $\Delta = 17$ ms; and trials with a loss distractor, $t(34) = 3.14$, $p = .004$, $d = 0.53$, $\Delta = 14$ ms (Figure 2A). Type of target (gain vs. loss) did influence ITs, $t(34) = 7.95$, $p < .001$, $d = 1.34$, with faster initiations for gain targets than for loss targets ($\Delta = 25$ ms), while the type of distractor did not, $t(34) = 0.68$, $p = .500$, $d = 0.12$.

Movement times. A significant effect of condition emerged, $F(4, 31) = 4.54$, $p = .005$, $\eta_p^2 = .37$, while the effect of delay and the interaction were not significant (Fs < 1.42,

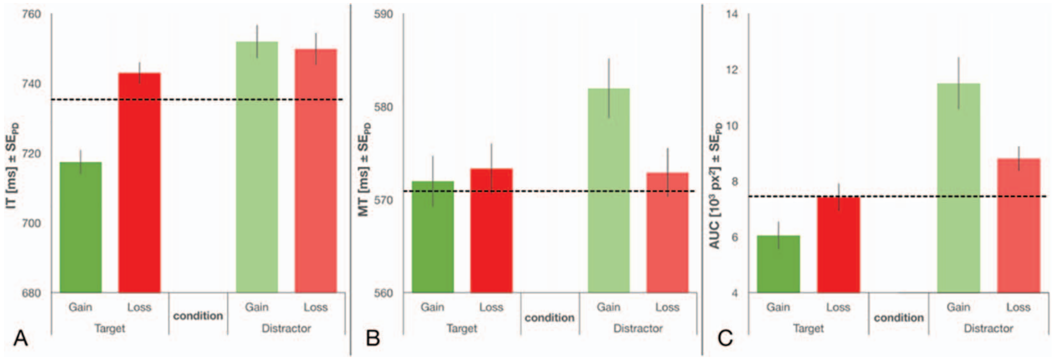

Figure 2. (A) Initiation times (ITs), (B) movement times (MT), and (C) areas under the curve (AUCs) in Experiment 1. Conditions with gain targets and distractors are depicted in green (light gray) and conditions with loss targets and distractors in red (dark gray). The baseline condition with neutral stimuli only is represented by the dotted line. Error bars represent standard errors of paired differences, calculated separately for each comparison between individual conditions and the baseline (Pfister & Janczyk, 2013). See the online article for the color version of this figure.

ps > .233). Only trials with gain distractors differed from the baseline, $t(34) = 3.45$, $p = .002$, $d = 0.58$, $\Delta = 11$ ms, while all other comparisons to the baseline returned nonsignificant results, ($|t|\text{s} < 1$; Figure 2B). Type of distractor (gain vs. loss) influenced MTs, $t(34) = 2.98$, $p = .005$, $d = 0.50$, with slower movements in the presence of gain distractors relative to loss distractors ($\Delta = 9$ ms), while the type of target made no difference, $t(34) = 0.46$, $p = .652$, $d = 0.08$.

Areas under the curve. A significant effect of condition emerged, $F(4, 31) = 10.95$, $p < .001$, $\eta_p^2 = .59$, while the effect of delay and the interaction were not significant (*F*s < 2.52, *ps* > .096). Trials with gain targets differed from the baseline, $t(34) = -2.82$, $p = .008$, $d = -0.48$, $\Delta = -1400$ px^2, as did trials with a gain distractor, $t(34) = 4.35$, $p < .001$, $d = 0.73$, $\Delta = 4051$ px^2, and trials with a loss distractor, $t(34) = 3.09$, $p = .004$, $d = 0.52$, $\Delta = 1356$ px^2. Only trials with a loss target did not differ from the baseline, $t(34) = -0.06$, $p = .952$, $d = -0.01$, $\Delta = -30$ px^2 (Figure 2C). Type of target (gain vs. loss) did influence AUC, $t(34) = 2.56$, $p = .015$, $d = 0.43$, with smaller areas under the curve for gain targets than for loss targets ($\Delta = 1369$ px^2), as did the type of distractor, $t(34) = 2.64$, $p = .012$, $d = 0.45$, with bigger AUCs for gain distractors than for loss distractors ($\Delta = 2695$ px^2).

Discussion

Experiment 1 examined whether presentations of goal-relevant stimuli associated with gains and losses affect the preparation and execution of an intended goal-directed action. First, the analysis of ITs revealed that loss targets and both motivational distractors delayed response initiation compared to the baseline. We take this as evidence for a time-consuming resolution of conflicting action tendencies. In contrast, gain targets accelerated response initiation compared to the baseline. The motivational impulse to procure a gain presumably converged in this condition with the task-defined action, which facilitated initiation of the corresponding action. This interpretation is also supported by the analysis of AUCs. Movement trajectories toward gain targets were more direct and showed less spatial extension. Importantly, analyses of AUCs further revealed that movements to neutral targets were strongly attracted toward the gain distractor. MTs and AUCs, however, provided no evidence for automatic avoidance of loss targets or loss distractors. Contrary to our hypothesis, movement trajectories were even shifted toward loss distractors, although the shift was greater with gain distractors. In short, movements were shaped only by presentations of stimuli associated with gains and not by loss-related stimuli.

One explanation for this motivational asymmetry is that the task setting induced a stronger focus on gains relative to losses. In fact, participants earned a point for each correct response (independent of the type of presented target), which means that point accumulation was emphasized more than a reduction of losses. Indeed, gaining points versus losing points is one way to induce regulatory foci of promotion and prevention situationally (Higgins, 1997). Self-regulation with a promotion focus strengthens approach-related actions, while the strength of avoidance-related actions increases with a prevention focus (Förster, Higgins, & Idson, 1998). Furthermore, motivational orientations on approach and avoidance facilitate the encoding of motivationally congruent information, while motivationally incongruent information attracts more attention (Gawronski, Deutsch, & Strack, 2005; Rothermund, 2003). If attentional processing was tuned to a promotion focus in the present experiment, it could explain why gain stimuli affected movement execution more than loss stimuli.

Experiment 2

Experiment 2 tested the motivational-tuning principle by using task settings that emphasized gains and losses, respectively. While a gain setting allowed participants to accumulate points at a fairly constant rate, as in Experiment 1, a loss setting required participants to compensate for a constant loss of points. Half of the participant sample started with the gain setting, the other half with a loss setting. After the first half of the experimental session, the setting was switched. We reasoned that if the motivational processing of targets and distractors is attuned to a promotion versus prevention orientation, effects of target and distractors on movement trajectories should be different in settings emphasizing gains and losses.

Method

Participants. A new sample of 40 participants was recruited (mean age = 24.9 years, *SD* = 6.8, 7 male, 5 left-handed) and received either course credit or €5 monetary compensation. All participants gave informed consent, were naïve to the purpose of the experiment, and were debriefed after the session.

Apparatus, stimuli, and procedure. The procedure was identical to that in Experiment 1 except for the following changes: While one task setting granted a bonus of +1 points for each correct response (as in Experiment 1), which made it possible to accumulate points, another task setting granted no such bonus, which made it impossible to reach a positive total score (the best possible outcome was 0 points). The first setting thus induced a focus on gains (i.e., a promotion focus), while the second setting induced a focus on losses (i.e., a prevention focus). Participants worked on the task in both motivational settings (with counterbalanced order). To minimize carry-over effects from the first to the second setting, the point score was reset after the first setting. Instructions in both settings were to earn/save as many points as possible.

Results

Data treatment and analyses. In the gain setting, participants gained 215 points (*SD* = 93.7) on average, whereas they lost 62 points (*SD* = 66.4) in the loss setting. The data were treated as in Experiment 1. We omitted trials in which participants failed to act according to the instruction or failed to hit any of the target areas at all (2.4%). Trials were discarded as outliers if any of the measures (IT, MT, AUC) deviated more than 2.5 *SD*s from the respective cell mean (5.0%). As delay (0.2 s, 0.3 s, 0.4 s) proved to be an additive factor in Experiment 1 that did not interact with any of the remaining factors, this factor was not included in the analyses reported below. Data were analyzed with a mixed 5 × 2 × 2 ANOVA, with condition and motivational task frame (promotion vs. prevention) as within-subjects factors and order of the motivation frame as a between-subjects factor. Specific contrasts were analyzed as in Experiment 1 (see Figure 3 for an overview of the results).

Initiation times. The main effect of condition was significant, $F(4, 35) = 11.93$, $p < .001$, $\eta_p^2 = .58$. The interaction between motivational task frame and order of the motivation frame reached significance, $F(1, 38) = 70.37$, $p < .001$, $\eta_p^2 = .65$, with ITs being faster for the promotion frame relative to the prevention frame for participants that started with the promotion frame and vice versa. Critically, the

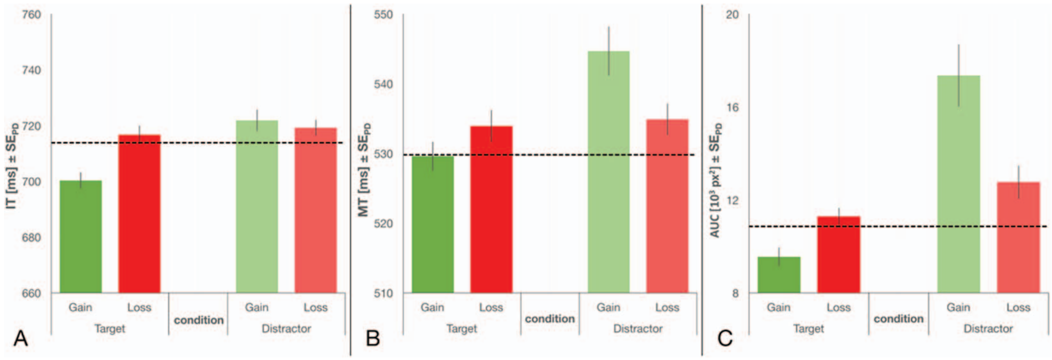

Figure 3. (A) Initiation times (ITs), (B) movement times (MT), and (C) areas under the curve (AUCs) in Experiment 2. Conditions with gain targets and distractors are depicted in green (light gray) and conditions with loss targets and distractors in red (dark gray). The baseline condition with neutral stimuli only is represented by the dotted line. Error bars represent standard errors of paired differences, calculated separately for each comparison between individual conditions and the baseline (Pfister & Janczyk, 2013). See the online article for the color version of this figure.

interaction between condition and motivational task frame was not significant, $F(4, 35) = 1.04$, $p = .400$, $\eta_p^2 = .11$; neither were any of the remaining effects (Fs < 2.00, ps $> .116$). Follow-up comparisons showed that trials with gain targets differed from baseline, $t(39) = -4.63$, $p < .001$, $d = -0.73$, $\Delta = -14$ ms, as did trials with a gain distractor, $t(39) = 2.09$, $p = .044$, $d = 0.33$, $\Delta = 8$ ms, and trials with a loss distractor (at least marginally), $t(39) = 1.91$, $p = .064$, $d = 0.30$, $\Delta = 5$ ms. Trials with a loss target did not differ from baseline performance, $t(39) = 0.86$, $p = .392$, $d = 0.14$, $\Delta = 3$ ms (Figure 3A). Type of target (gain vs. loss) influenced ITs, $t(39) = 5.13$, $p < .001$, $d = 0.81$, with faster ITs for gain targets than for loss targets ($\Delta = 16$ ms), while type of distractor had no effect, $t(39) = 0.92$, $p = .363$, $d = 0.15$.

Movement times. A significant effect of condition emerged, $F(4, 35) = 4.95$, $p = .003$, $\eta_p^2 = .36$. The interaction between motivational task frame and order of the task framing was significant, $F(1, 38) = 51.67$, $p < .001$, $\eta_p^2 = .58$, again showing faster movement times for the framing that was first presented. Importantly, the interaction between condition and setting was not significant ($F<1$); neither were any of the remaining effects (Fs < 1.83, ps $> .145$). Movements with gain distractors were executed slower compared to baseline, $t(39) = 4.21$, $p = .002$, $d = 0.67$, $\Delta = 15$ ms, as did trials with loss distractors, $t(39) = 2.26$, $p = .029$, $d = 0.36$, $\Delta = 5$ ms. All other comparisons with baseline returned nonsignificant results ($|t|$s < 1.8, ps $> .079$; Figure 3B). Type of target (gain vs. loss) influenced MTs, $t(39) = 2.28$, $p = .028$, $d = 0.36$, with slower movements for loss targets than for gain targets ($\Delta = 4$ ms), as did the type of distractor, $t(39) = 3.32$, $p = .002$, $d = 0.52$, with slower movements for gain distractors than for loss distractors ($\Delta = 10$ ms).

Areas under the curve. The main effect of condition was significant, $F(4, 35) = 8.35$, $p < .001$, $\eta_p^2 = .49$. The effect of motivational task frame was also significant, $F(1, 38) = 13.78$, $p = .001$, $\eta_p^2 = .27$, with bigger AUCs with a loss frame (13,822 px^2) than with a gain frame (10,894 px^2). A significant interaction between motivational task frame and task frame order, $F(1, 38) = 28.15$, $p < .001$, $\eta_p^2 = .43$, revealed smaller areas under the curve for the second setting of the experiment relative to the first setting that participants experienced. As in the other measures, the interaction between condition and setting was not significant, $F(4, 35) = 1.98$, $p = .118$, $\eta_p^2 = .19$. No other effects were significant (Fs < 2.45, ps $> .065$). Follow-up comparisons showed that trials with gain targets differed from baseline, $t(39) = -3.27$, $p = .002$, $d = -0.52$, $\Delta = -1307$ px^2, as did trials with a gain distractor, $t(39) = 4.83$, $p < .001$, $d = 0.76$, $\Delta = 6486$ px^2, and trials with a loss distractor, $t(39) = 2.65$, $p = .011$, $d = 0.42$,

$\Delta = 1902$ px^2. Movements to a loss target were not different from baseline, $t(39) = 1.12$, $p = .268$, $d = 0.18$, $\Delta = 423$ px^2 (Figure 3C). Type of target (gain vs. loss) affected the area under the curve, $t(39) = 4.41$, $p < .001$, $d = 0.70$, with smaller AUC for gain targets than for loss targets ($\Delta = 1730$ px^2). AUC was also bigger with presentations of gain distractors relative to loss distractors ($\Delta = 4584$ px^2), $t(39) = 4.80$, $p < .001$, $d = 0.76$.

Discussion

Experiment 2 investigated whether effects of motivational targets and distractors on movement trajectories are different in task settings that emphasize gains versus losses (promotion vs. prevention). Results replicated the facilitation effect of gain targets on action planning and the attraction-interference by gain distractors during movement execution; however, the motivational task frame did not modulate these effects. Thus, results of Experiment 2 do not support a strong explanation of the attraction-effect with motivational tuning but rather suggest the attraction effects observed in Experiment 1 to be a robust phenomenon.

Experiment 3

Experiments 1 and 2 provided evidence that appetitive stimuli (associated with a point gain) expedite and attract movements toward them, while aversive stimuli (associated with a point loss) produced far smaller effects or had no effect on movement control. Yet, this asymmetry could be explained with differences in the relevance of gains and losses in these experiments:[1] Since errors were always punished with a deduction of 10 points, there was more at stake in trials with movements to a gain target, because here an incorrect response was costlier (−10 instead of +6; $\Delta = 16$ points) in comparison to trials with a movement to the loss target (−10 instead of −4; $\Delta = 6$ points). It should be noted that this difference does not apply to the conditions with gain and loss distractors, because here an error was equally costly (−10 instead of +1; $\Delta = 11$ points). Still, our payoff matrix might have rendered gain targets, and by association, the target area linked to gains, more relevant. Thus, it is possible that the payoff matrix had biased the results of Experiments 1 and 2. To disentangle effects of motivational valence from effects of task relevance, we made adjustments to the payoff matrix for Experiment 3: Bonuses that were associated with reaching a target area were now granted irrespective of whether a correct or an incorrect response was given. That means, if a movement to a gain target was instructed, participants earned a 5-point bonus even if the other location (the distractor) was reached. Participants lost 5 points in trials with a loss target even if this target was not reached. In trials with neutral targets (and with gain or loss distractors), no additional bonus was granted (except for a small +1 bonus for a correct response), even if the response ended on a gain or loss distractor. As now in every trial, both the correct and the incorrect responses produced the gain or loss associated with the target; motivational valence and task relevance were no longer confounded. Experiment 3 tested how this adjusted payoff matrix would influence movement control.

Method

Participants. A new sample of 40 participants was recruited (mean age = 25.1 years, *SD* = 4.1, 14 male, 4 left-handed) and received either course credit or €5 monetary compensation. All participants gave informed consent, were naïve to the purpose of the experiment, and were debriefed after the session. One participant was removed from the sample due to high error rates (>30%).

Apparatus, stimuli, and procedure. The procedure was identical to Experiment 1 except for the following changes: The point score (gain or loss) of the designated target area was now granted after every registered response (i.e., irrespective of the correctness of the response). Thus, responding in trials with a gain target produced a gain of 5 points (even if reaching the alternative location), and responding in trials with a loss target produced a loss of 5 points (even if reaching the alternative location). A correct response was still rewarded with a bonus of 1 point (+1), and an incorrect response (or omission) was punished with a subtraction of 1

[1] We thank Klaus Rothermund, who commented on a previous version of this article, for this remark, and for inspiring Experiment 3.

point (−1). That way, the influence of the gain and loss targets could no longer be avoided (as the bonus for a trial was always given); in addition, each trial motivated participants to respond correctly to gain 1 point (and to avoid the loss of 1 point).

Results

Data treatment and analyses. Overall, participants gained 472 points (*SD* = 123.9) on average. The data were treated as in Experiment 1. We omitted trials in which participants failed to act according to the instructions or failed to hit any of the target areas at all (3.4%). Trials were discarded as outliers if any of the measures (IT, MT, AUC) deviated more than 2.5 *SD*s from the respective cell mean (5.5%). The data were analyzed with a repeated-measures ANOVA with condition as a single factor. Specific contrasts were analyzed as in Experiment 1 (see Figure 4 for an overview of the results).

Initiation times. The effect of condition was significant, $F(4, 35) = 10.24$, $p < .001$, $\eta_p^2 = .54$. ITs in trials with a gain target were faster relative to the baseline performance, $t(38) = -5.01$, $p < .001$, $d = -0.80$, $\Delta = -16$ ms. Performance in the other conditions did not differ from baseline ($|t|$s < 1.09, $ps > .281$; Figure 4A). Type of target (gain vs. loss) influenced ITs, $t(38) = 5.96$, $p < .001$, $d = 0.96$, with faster ITs for gain targets than for loss targets ($\Delta = 20$ ms), while the type of distractor did not, $t(38) = -0.13$, $p = .897$, $d = -0.04$.

Movement times. A significant effect of condition emerged, $F(4, 35) = 5.17$, $p = .002$, $\eta_p^2 = .37$. Movements with gain distractors were executed slower compared to baseline, $t(38) = 4.19$, $p < .001$, $d = 0.67$, $\Delta = 11$ ms. Other comparisons returned nonsignificant results ($|t|$s < 1.86, $ps > .071$; Figure 4B). Type of target (gain vs. loss) influenced MTs, $t(38) = -2.96$, $p = .005$, $d = -0.47$, with faster movements to gain targets relative to loss targets ($\Delta = -7$ ms). Type of distractor had no effect, $t(38) = 1.61$, $p = .117$, $d = 0.25$.

Areas under the curve. A significant effect of condition emerged, $F(4, 35) = 10.66$, $p < .001$, $\eta_p^2 = .55$. Trials with gain targets differed from the baseline, $t(38) = -2.26$, $p = .030$, $d = -0.36$, $\Delta = -921$ px^2, as did trials with a gain distractor, $t(38) = 5.76$, $p < .001$, $d = 0.92$, $\Delta = 6173$ px^2, and trials with a loss distractor, $t(38) = 4.09$, $p < .001$, $d = 0.66$, $\Delta = 2542$ px^2. Only trials with a loss target did not differ from the baseline, $t(38) = 1.82$, $p = .075$, $d = 0.29$, $\Delta = 935$ px^2 (Figure 4C). Type of target (gain vs. loss) affected AUCs, $t(38) = 4.28$, $p < .001$, $d = 0.68$, with smaller AUC for gain targets than for loss targets ($\Delta = 3630$ px^2). Type of distractor had also an effect, $t(38) = 3.75$, $p = .001$, $d = 0.60$, indicating

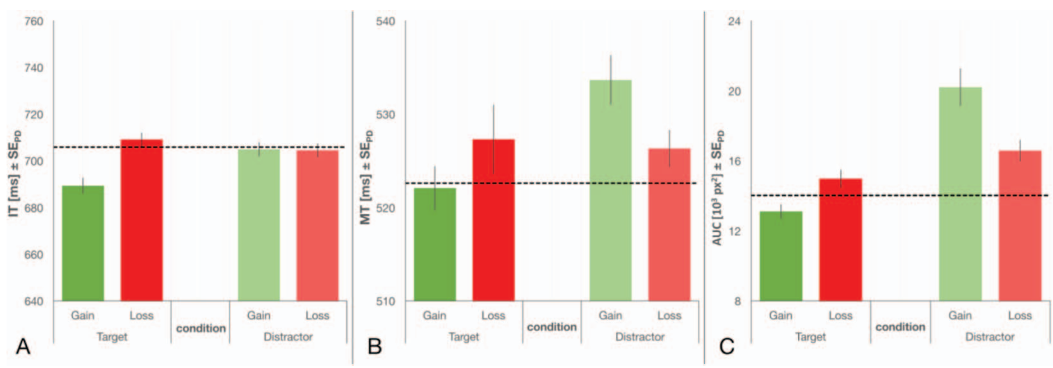

Figure 4. (A) Initiation times (ITs), (B) movement times (MT), and (C) areas under the curve (AUCs) in Experiment 3. Conditions with gain targets and distractors are depicted in green (light gray) and conditions with loss targets and distractors in red (dark gray). The baseline condition with neutral stimuli only is represented by the dotted line. Error bars represent standard errors of paired differences, calculated separately for each comparison between individual conditions and the baseline (Pfister & Janczyk, 2013). See the online article for the color version of this figure.

bigger AUCs for gain distractors relative to loss distractors ($\Delta = 1856$ px^2).

Discussion

Experiment 3 replicated the findings of Experiment 1 with an adjusted payoff matrix that controlled for differences in the task relevance of gain and loss targets. Movements to gain targets were initiated faster, and movement execution was attracted toward distractor areas associated with gains. Targets and distractors associated with loss produced only small effects and affected movement trajectories less strongly. Time for action planning for any other condition than gain targets did not differ from the baseline condition, which seems to suggest that the resolution of conflicting action tendencies by suppressing automatic motivational impulses is less strong of an effect than initially believed (cf. Experiment 1). Furthermore, these results corroborate the previous findings that rewarding stimuli have a stronger impact on movement execution than their punishing counterparts.

General Discussion

The present research recorded continuous finger movements on a touchscreen to investigate the impact of goal-relevant stimuli on movement initiation and movement trajectories. Results of three experiments showed that approach to a rewarding target facilitated response initiation, while participants needed equal time (Experiments 2 and 3) or even more time (Experiment 1), relative to a neutral baseline, when they had to approach a punishing target. Distractors associated with both reward and punishment affected action planning similarly. Thus, one cannot infer from reaction time effects alone whether the delay was caused by a conflicting motivation to avoid a loss or by a motivation to approach gains. Spatial indices of action execution, by contrast, were able to differentiate between appetitive and aversive impulses. While movement trajectories were attracted toward the gain distractor, in line with a hypothesized pull of rewards, there was no deflection in the movement trajectories away from loss targets, and only a slight deflection toward loss distractors. This pattern was also observed in a task setting that induced a stronger focus on losses than on gains (Experiment 2), and with a payoff structure that does not confound motivational valence from task relevance (Experiment 3). Thus, movement execution was influenced in the present research almost exclusively by stimuli associated with rewards. Targets and distractors associated with punishment tended to delay action initiation (showing that they were motivationally processed; except for Experiment 3) but they did not deflect movements away from them.

One way to make sense of this motivational asymmetry in the trajectory measure is to rethink the way in which approach and avoidance motivation is translated into an action impulse. Standard motivation theories typically claim that the capacity to evoke approach and avoidance response resides in the stimulus: So-called "appetitive stimuli" trigger a behavioral set related to approach (to consume, attach, make contact, etc.), while so-called "aversive stimuli" trigger behavior associated with avoidance (to defend, reject, increase distance, etc.; e.g., Konorski, 1967; Lang, Bradley, & Cuthbert, 1990). For the present paradigm, this means that stimuli associated with gains should have attracted movements toward them (which was indeed observed), while stimuli associated with losses should have pushed movement trajectories away from them (which was not observed). However, an alternative possibility is that approach and avoidance motivations are not tied to a fixed set of behavioral or functional responses, but are configured in accordance with the action repertoire that is available for a given situation (Eder & Hommel, 2013). In the present paradigm, for instance, the action repertoire was restricted to swipe movements toward areas designated as targets. This is especially relevant for the current operationalization of loss targets. Even though these targets signaled an overall loss of points, moving to these targets still was the only sensible option in this condition because every other response (i.e., responses toward the alternative target or misses) would incur an even bigger loss. Participants were thus always prepared to perform particular movements and the valence or attractiveness of the action target was likely integrated into the movement plan (Eder & Klauer, 2009). It is now assumed that integrated affective features modulate the activation strength of the corresponding action representation, with positive valence increasing the motivational readiness and negative features decreasing it (Eder, Rothermund, De Houwer, & Hommel, 2015; for a related approach, see Marien, Aarts, & Custers, 2013). Actions leading to a desired outcome (e.g., a gain) are consequently motivationally readied in comparison to actions leading to a negative outcome (e.g., an unavoidable loss), which means that a rewarded action is activated more easily by associated stimuli (even when such activation is not appropriate). As a result, stimuli associated with gains attract movement trajectories by activating a movement plan that leads to them, while stimuli associated with losses do not have this capacity. According to this account, movements leading to a loss (punishment) are inhibited or executed with more caution (McNaughton & Corr, 2004). However, the stimulus association with a loss is not sufficient to trigger behavioral avoidance as long as this action is not part of the local action repertoire.

While the context of overall gain and loss framing did not affect the present results, we do not wish to argue that the way participants conceive the payoff structure of a task has no influence on goal-directed action. For instance, a promotion focus was shown to increase the ability to control impulsive actions (Dholakia, Gopinath, Bagozzi, & Nataraajan, 2006). Furthermore, affective evaluation of stimuli associated with gains and losses depends on the overall payoff structure (Eder & Dignath, 2014). Moreover, it is possible that the payoff manipulation in Experiment 2 was too weak for an induction of different motivational orientations. Future research may therefore use alternative or more powerful manipulations to this end (see, e.g., Förster et al., 1998; Rothermund, Voss, & Wentura, 2008). Furthermore, emotional stimuli may have a stronger impact on movement execution. One study investigated reach trajectories of spider-fearful participants who moved their hand either away or toward the picture of a spider. Results revealed more direct reaching movements away from the spider picture and less direct movement trajectories toward the threatening target relative to nonanxious controls (Buetti, Juan, Rinck, & Kerzel, 2012). This research suggests that effects of aversive stimuli on movement execution are stronger when they are emotionally processed.

The idea that target and distractor processing is altered by reward prospect has also gained a considerable amount of interest in the study of selective attention (for a review, see Chelazzi, Perlato, Santandrea, & Della Libera, 2013). Numerous studies provided evidence that previously learned reward association facilitate target detection (negative priming, Della Libera & Chelazzi, 2006; attentional blink, Raymond & O'Brien, 2009; Stroop task, Krebs, Boehler, & Woldorff, 2010; visual search, Della Libera & Chelazzi, 2009) and impair distractor suppression (attentional capture, Anderson, Laurent, & Yantis, 2011; Stroop task, Krebs et al., 2010). Notably, we know of no study that investigated effects of rewarding and punishing targets and distractors in a single paradigm. The present paradigm allows a direct comparison of the motivational processing of targets and distractors, suggesting that rewarding distractors and targets affect specific movement phases differently.

To summarize, the present study examined motivational effects of rewarding and punishing stimuli on action control. Using a movement task in which rewarding and punishing stimuli were presented as targets and distractors for a reaching movement, we show that different phases of a movement are distinctly shaped by appetitive and aversive impulses: While punishing stimuli had little to no effect on movement control, rewarding targets facilitated response initiation and rewarding distractors impaired response execution.

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