Motivation drives conflict adaptation

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Abstract

The notion that impaired performance in the past increases motivational vigor in the future is central to many modern theories. The conflict monitoring model predicts that conflict between incompatible responses reduces susceptibility to upcoming conflict. Recently, this conflict-adaptation effect has been reframed in terms of motivational control: Conflict in the past elicits negative affect, which can be reduced by increasing control, thereby alleviating future conflict and associated negative affect. While evidence supports that conflict adaptation serves a motivational purpose (e.g., affect regulation), it remains unclear whether conflict adaptation is actually triggered by motivational mechanisms. The present research tested this hypothesis of a motivational conflict-adaptation effect. We recorded continuous finger movements towards target stimuli and away from distractor stimuli. Motivational conflict was instigated by assigning reward and penalty to stimuli that functioned either as targets or distractors. To index motivational vigor and increased precision due to motivation, we measured initiation times and spatial deviation from the shortest path to the target. Both a re-analysis of published data and data from a new replication study established a motivational conflict-adaptation effect. Together, the results extend a motivational control framework, showing that motivational dynamics (i.e., motivational conflicts) can be the driving force of control. [200]

Keywords: conflict adaptation; motivation; conflict monitoring, continuous movement

Introduction

When facing difficulties, people have the remarkable ability to persist and overcome obstacles. But how do we know when to put more effort in a task? In theory, it has been argued that the difficulty of an action motivates additional effort investment (Ach, 1935; Brehm & Self, 1989; Trope & Fishbach, 2000; Gendolla & Richter, 2010). For instance, the *conflict monitoring model* (Botvinick, Braver, Barch, Carter, & Cohen, 2001) proposed that recent difficulty, as indexed by conflict between incompatible responses, is used as a teaching-signal to upregulate control. Behaviorally, the so-called *conflict-adaptation effect* provides an index for this increase in control – when a conflicting stimulus was encountered in the previous trial, conflict has less detrimental consequences in the following trial (Gratton, Coles, & Donchin, 1992). Further support for a motivational account of the conflict-adaptation effect comes from studies showing that conflict triggers negative affect (Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013), increases avoidance motivation (Dignath & Eder, 2015; Dignath, Kiesel, & Eder, 2015), and from studies suggesting that adaptation to conflict is modulated by affect and rewards (Braem, Verguts, Roggeman, & Notebaert, 2012; Van Steenbergen, Band, & Hommel, 2009; but see Dignath, Janczyk, & Eder, 2017).

While there is good reason to assume that conflict adaptation serves a motivational purpose (Dreisbach & Fischer, 2015; Inzlicht, Bartholow, & Hirsh, 2015), the role of motivation as a trigger for conflict adaptation remains unclear. Here we tested the possibility that conflict adaptation is driven by motivational conflict. To induce conflicting motivations, we presented stimuli that were associated with reward or penalty. To disentangle cognitive conflict from motivational conflict, we ruled out any

differences between targets and distractors in terms of overlearned behavior (e.g., Stroop), automatic activation of responses (e.g., Simon task) or spatial proximity (e.g., flanker task) and selectively manipulated the value-association of target and distractor. Following previous work, we hypothesized that value energizes corresponding actions, causing conflict if the distractor is motivational, but not the target, and causing no conflict if the target is motivational, but not the distractor (Dignath, Pfister, Eder, Kiesel, & Kunde, 2014; Wirth, Dignath, Pfister, Kunde, & Eder, 2016).

To provide direct evidence for the assumption that motivational conflict drives conflict adaptation, we measured continuous recordings of finger movements towards targets and away from distractors. Because recent research has shown that motivation not only increases speed, but also reduces noise of motor signals (Manohar et al., 2015) we considered both the speed of action initiation (as an indicator of vigor; Niv, Daw, Joel, & Dayan, 2007) and the spatial variability of movement execution (as an indicator of precision; Summerside, Shadmehr, & Ahmed, 2018).

Experiment

The present research used a finger tracking paradigm to measure continuous movements. Participants moved towards a target while a distractor was presented at the opposite location. Target and distractor were defined at the beginning of each trial by a spatial-cue. To manipulate motivational valence, points were assigned according to the color of the target stimulus (the color pay-off regime from hereon): In trials with a gain-colored target, participants received 5 points; in trials with a loss-colored target, they lost 5 points and in trials with a neutral-colored target, they received zero points. Importantly, this pay-off was independent of the actual performance. Therefore,

participants could not avoid a penalty in trials with a loss target, e.g., by selecting a neutral distractor. Conversely, since points were only assigned to target stimuli, participants could not gain extra points, e.g., by selecting a gain distractor. As a consequence any influence of gain/ loss distractors reflects value-learning of color-incentive associations during target trials. Independently from the color pay-off regime, additional points were assigned according to the performance in a trial: errors (wrong responses and omissions) were punished with -1 point and correct responses were rewarded with +1 point.

In the motivational-target condition a gain or loss-colored target was presented along with a neutral distractor; in the motivational-distractor condition a gain or loss-colored distractor was presented along with a neutral target; and in the neutral-condition, a neutral-colored target was presented along with a neutral-colored distractor. In the present context, the term motivational target/ distractor refers to both reward and penalty, because research has shown that not only rewards, but also penalties have an energizing effect on behavior and speed-up responses towards punishment (Neiss, 1988; Eder, Dignath, Erle, & Wiemer, 2017; for additional analysis of the present data that considers the valence of targets/distractors, see supplement 3; table 1 provides an overview of the supplement).

Our hypothesis of a motivational conflict-adaptation effect predicts that motivational conflict in the previous trial mitigates the impact of motivational conflict in the current trial (see Figure 1, lower panel for an illustration). We measured initiation times (ITs) of movements as an indicator of motivational vigor. To index precision, we measured variability of movement trajectories in each trial (see Figure 1, upper panel for

an illustration of the trial sequence and the DVs). To test this hypothesis, we first re-analyzed a data-set previously reported in a different context (Wirth et al., 2016, Exp. 3) and then replicated this finding in a new sample. Both analyses returned similar results, and for brevity, we present here only confirmatory tests of the replication study (reanalysis of the published data can be found in supplement 1).
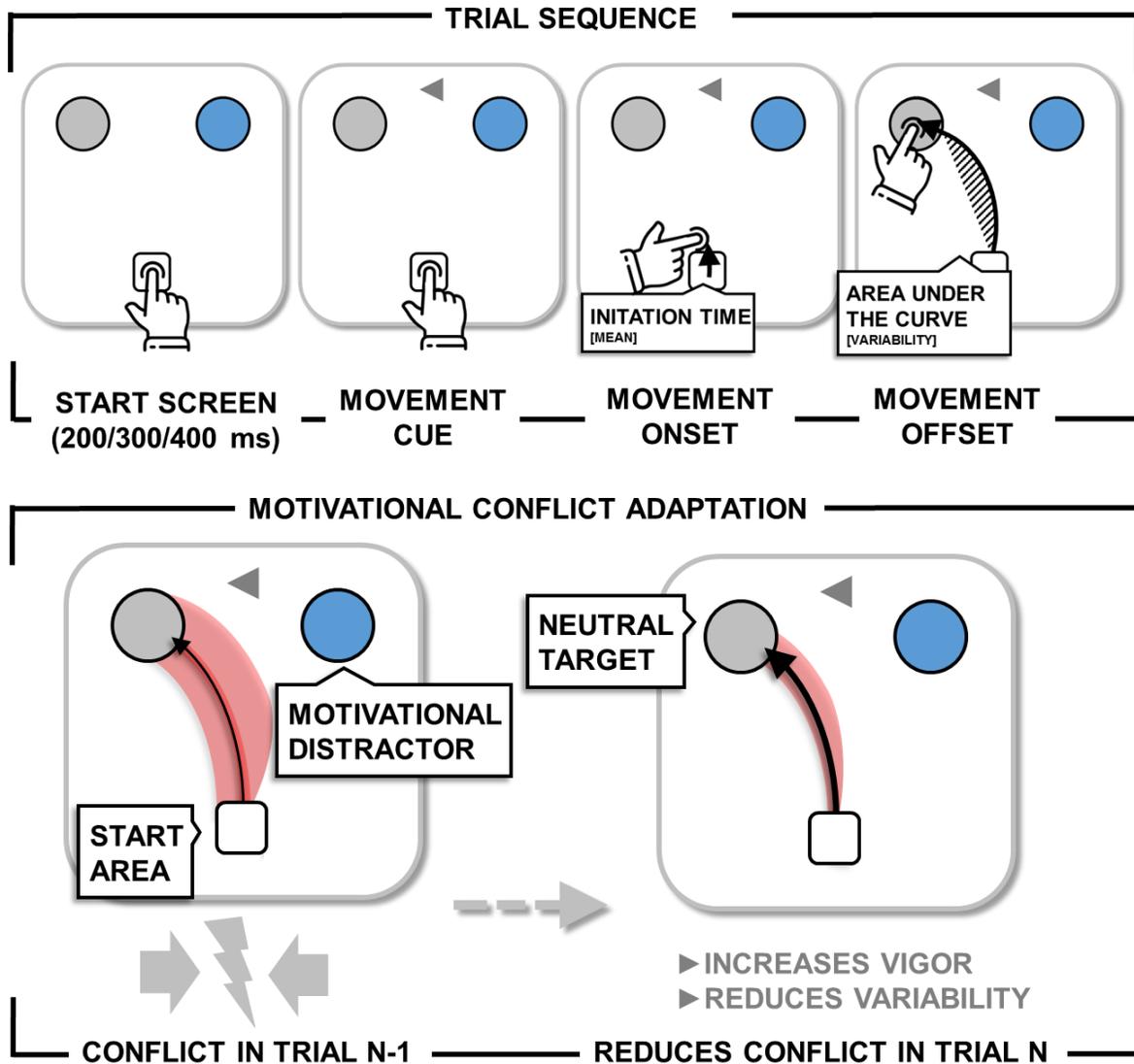
Figure 1. Upper panel: Illustration of the trial sequence and depend variables. Participants started a trial by touching the start area with their index finger. After a variable dwell interval, jittered between 200 and 400 ms, the movement cue indicated the target. The initiation times reflected the time from cue onset until the finger left the start area and provides an index how fast the movement was started. The standard deviation of the area under the curve reflected the spatial deviation between the actual trajectory and a straight line from start- to endpoint and provides an index of variability of the movement.

Lower panel: Illustration of the hypothesized motivational conflict adaptation effect: Motivational conflict (i.e., moving towards a neutral target in the presence of a motivational distractor [reward or penalty]) in the previous trial reduces the impact of motivational conflict in the current trial.

Method

The present experiment is a direct replication of Experiment 3 of Wirth et al. (2016). For completeness, an analysis analog to the one reported in Exp. 3 in the original paper can be found in supplement 4.

Participants. Sixty-five participants were recruited (mean age = 21.3 years, *SD* = 3.8, 7 male, 6 left-handed) and received course credit. Given an effect size of *d* = .4 in the re-analysis of our published data, this sample sizes allowed to replicate conflict-adaptation effects (AUC$_{SD}$) with a power of 88% (alpha-level of .05, two-sided). All participants gave informed consent, were naïve to the purpose of the experiment and were debriefed after the session. Data of one participant was replaced by a new participant due to technical difficulties during testing.

Apparatus and stimuli. All materials and procedure were identical to Wirth et al., 2016, Exp. 3. The experiment was run on an iPad (movements sampled at 100 Hz). The starting position (Ø 1cm) was located at the bottom center of the screen; target and distractor (Ø 2cm) were presented in the upper left and right corners of the display in either blue, yellow (color-value mapping counterbalanced across participants) or gray (neutral). Arrow cues prompted movements to the target (presented at the top of the screen). Each combination of motivational target/ neutral distractor and neutral target/ motivational distractor was presented ten times per block. Additionally, label trials (randomly intermixed four times per block) were used to strengthen the color-value association during the experiment (not included in the analyses). In these trials, gain and loss colors were presented simultaneously, and a plus or minus sign indicated whether participants had to reach the gain or the loss stimulus.

Procedure. Participants touched the starting area with the index finger of the dominant hand to start a trial. Simultaneously, the two circles in the upper half of the screen appeared and after a dwell time of 200/300/400ms (chosen randomly for each trial), an arrow indicated the current target. Participants were then to execute a smooth and continuous movement to the target as quickly as possible. Instructions emphasized to accumulate as many points as possible (participant's score was presented at the top). Points were calculated based on the color pay-off and the performance-contingent pay-off regime independently (see above for details). Overall, participants completed 10 blocks of 58 trials each.

Results

Preprocessing. We focused on two complementary DVs to assess motivational drive and analyzed the average time to initiate movements (IT_{mean}) and the average variability of the area under the curve (AUC_{SD}) between the actual trajectory and a straight line from start- to endpoint. For completeness, similar analysis for movement time and mean AUC can be found in supplement 2. Movements to the left were mirrored at the vertical midline for all analyses. AUC was computed from the time-normalized coordinate data of each trial by using custom MATLAB scripts (The Mathworks, Inc.) as the signed area relative to a straight line from start- to endpoint of the movement (positive values indicating attraction toward the distractor, negative values indicating attraction toward the edge of the display).

Data selection and analyses. Participants gained 546 points on average (SD = 25.7). For the following analyses, we removed error trials and response omissions

(2.9%). Trials were discarded as outliers if any of the DVs deviated more than 2.5 SDs from the respective cell mean (5.3%).

Overall conflict adaptation. In the present study, we were interested in whether motivational conflict triggers conflict adaptation. To investigate this question, we first computed the conflict-adaptation effect for IT_{mean} and AUC_{SD}. The difference between conflict (C) vs. non-conflict trials (I) after previously non-conflict (c) trials and conflict vs. non-conflict trials after previously conflict (i) trials provides an index of conflict adaptation = (cI − cC) − (iI − iC). Both measures produced significant conflict-adaptation effects, IT_{mean}, $t(64) = 2.32$, $p = .024$, $d = 0.29$ and AUC_{SD}, $t(64) = 4.32$, $p < .001$, $d = 0.53$, indicating that previous motivational conflict reduced the impact of motivational conflict in the current trial. As shown in Figure 2 (i.e. the difference between the green and red lines depending on previous trial type), conflict in the previous trial increased vigor and decreased variability in the next trial to counteract further conflict.

Reduced distractor susceptibility vs. increased target processing. Next, we investigated whether motivational conflict adaptation was driven by enhanced target focus or increased shielding against distractors. Therefore, we included trials following the neutral baseline condition (see Figure 2, right side of each plot) and analyzed overall performance with the factors previous trial type (motivational target vs. motivational distractor vs. baseline) and current trial type (motivational target vs. motivational distractor). Statistically, the interaction between both factors indicates a possible difference in processing (target facilitation vs. distractor shielding) following conflict.

For IT_{mean}, the main effect previous trial, $F(2,63) = 4.75$, $p = .012$, $\eta_p^2 = .13$ showed slower response initiation after motivational distractors (691ms) than after motivational targets (686ms) or baseline (686ms), $ts \geq 2.49$, $ps \leq .015$, $ds \geq 0.31$, and no significant difference between the latter conditions, $t < 1$. The main effect of current trial, $F(1,64) = 15.44$, $p < .001$, $\eta_p^2 = .19$ indicated faster response initiation for motivational targets (684ms) than for motivational distractors (692ms) . The interaction was not significant, $F(2,63) = 2.94$, $p = .060$. Analysis of AUC_{SD} showed a main effect of previous trial, $F(2,63) = 6.14$, $p = .004$, $\eta_p^2 = .16$, with larger variability after motivational targets (18226px^2) than after motivational distractors (16682px^2) or baseline (17052px^2), $ts \geq 2.44$, $ps \leq .017$, $ds \geq 0.30$, and no difference between the latter conditions, $t < 1$. Further, there was a main effect of the current trial, $F(1,64) = 83.47$, $p < .001$, $\eta_p^2 = .56$, with higher spatial variability for motivational distractors (20248px^2) than for motivational targets (14393px^2). The significant interaction, $F(2,63) = 9.88$, $p < .001$, $\eta_p^2 = .24$, indicated smaller differences between current motivational targets and motivational distractors after a motivational distractor ($\Delta = 4118$px^2) than after a motivational target ($\Delta = 7451$px^2) or baseline trials ($\Delta = 5996$px^2), $ts \geq 2.07$, $ps \leq .043$, $ds \geq 0.26$, and no difference between the latter conditions, $t(64) = 1.37$, $p = .176$, $d = 0.17$. In other words, spatial variability of movements in motivational conflict trials is reduced following conflict, indicating better shielding against distraction, while target processing was not facilitated by previous conflict.
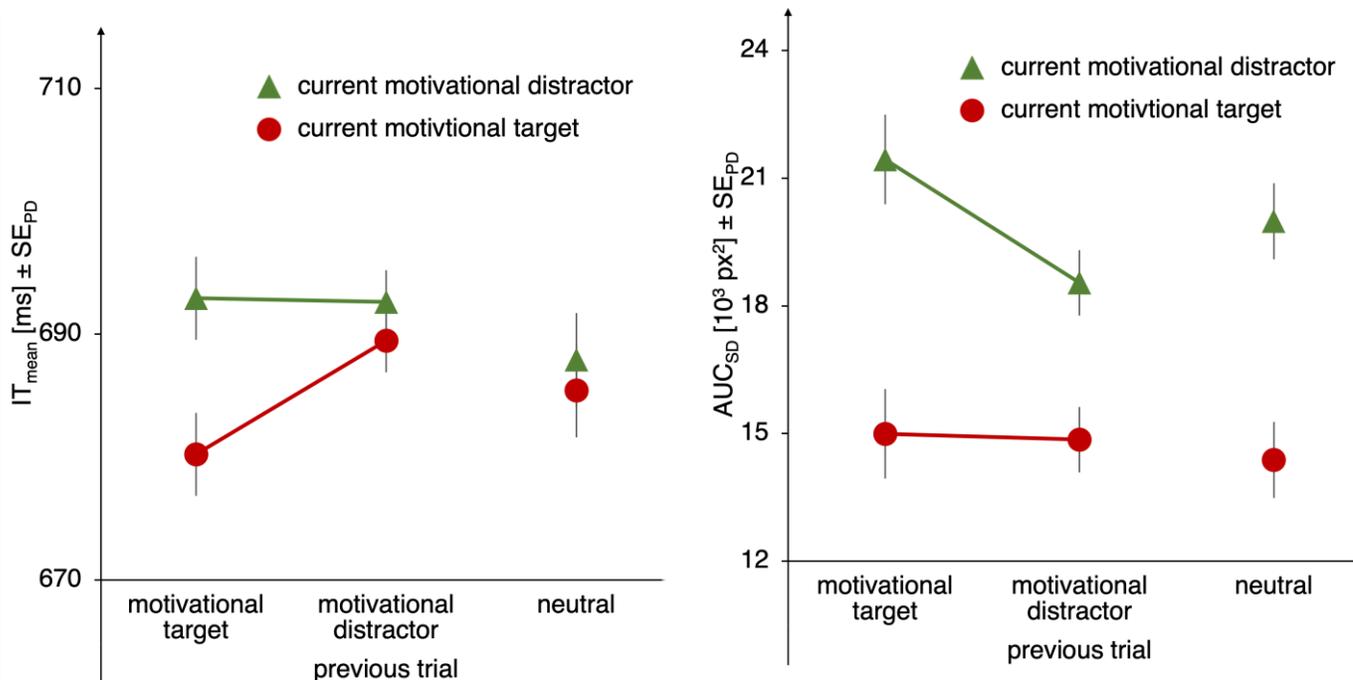
Figure 2. Mean ITs (left) and standard deviation of AUCs (right) for current motivational targets (red lines) and current motivational distractors (green lines), separate for trials after motivational targets, after motivational distractors, and after neutral baseline trials.

Discussion

The present study tested whether previous motivational conflict causes adaptation to conflict in the current trial. Results from a re-analysis of a previous data-set and a new replication provided converging evidence for *motivational* conflict-adaptation effect – prior motivational conflict alleviates future conflict. This is in line with recent research on decision making (Heitmann & Deutsch, 2018), showing faster decisions following motivational conflict compared to control trials. Moreover, it provides further support for theoretical accounts that aim to explain why and how people overcome obstacles during goal pursuit (e.g., Botvinick et al., 2001; Inzlicht et al., 2015;

see also Shenhav, Botvinick & Cohen, 2013). The present results extend this framework, showing that control mechanisms not only serve motivational functions, but that motivational conflict is a driving force of control in itself.

Closer inspection of the results (Figure 2) suggests that motivational conflict adaptation during movement execution was caused by an increased shielding against distraction. In contrast, conflict-adaptation effects in movement initiation seemed to be more likely due to increased target processing following conflict, although it should be noted that the critical comparison against baseline failed to reach significance in the confirmatory study (p = .060). Why did the mechanisms underlying conflict adaptation differ between DVs? One plausible explanation is that action initiation and execution reflect distinct processes underlying control (Song & Nakayama, 2009). For instance, for conflict-adaptation effects in the Stroop task, it has been suggested that action initiation describes an reactive change in control, while action execution reflects monitoring of conflict (Erb & Marcovitch, 2018; Erb, Moher, Sobel, & Song, 2016). Furthermore, neurophysiological work found that distinct neuronal populations code separately for action initiation and execution (Gaidica, Hurst, Cyr, & Leventhal, 2018). However, it is unclear how such a sharp distinction translates into continuous processing models suggesting a constant flow of information from beginning until the end of an action (Miller, 1988; Pfister, Janczyk, Wirth, Dignath, & Kunde, 2014; Spivey, Grosjean, & Knoblich, 2005). Clearly, more research is needed to determine when and how control is instigated during motivational conflicts.

In previous work (and also in this study, see supplement 4) an asymmetric influence of the current motivational distractor on movement execution was observed.

More specifically, movement execution showed an increased pull towards gain distractors, while targets and distractors associated with losses had no effect on movement execution. Why did this valence asymmetry in the current trial not influence conflict-adaptation effects? In theory, the control signal is indexed by competing response activation. Possibly, conflict monitoring is confined to the response preparation stage and later conflict during response execution does not feed into the control signal. This speculation fits with research on dorsal stream processing during movement execution, which is often assumed to run encapsulated from other ongoing processing (e.g., Milner, 2017; but see Erb et al., 2016).

Summary

This experiment (and a re-analysis of a previous data-set) tested a key prediction of a motivational view of conflict adaptation, suggesting that previous motivational conflict reduced susceptibility to current motivational conflict. Using a simple measure of motivational vigor and precision, we provided evidence that supports this prediction by showing that previous motivational conflict drives control adaptation.

Table 1. Index of supplementary materials (available at https://osf.io/tdegq/)

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