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The influence of approach–avoidance motivational orientation on conflict adaptation

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Abstract To deal effectively with a continuously changing environment, our cognitive system adaptively regulates resource allocation. Earlier findings showed that an avoidance orientation (induced by arm extension), relative to an approach orientation (induced by arm flexion), enhanced sustained cognitive control. In avoidance conditions, performance on a cognitive control task was enhanced, as indicated by a reduced congruency effect, relative to approach conditions. Extending these findings, in the present behavioral studies we investigated dynamic adaptations in cognitive control—that is, conflict adaptation. We proposed that an avoidance state recruits more resources in response to conflicting signals, and thereby increases conflict adaptation. Conversely, in an approach state, conflict processing diminishes, which consequently weakens conflict adaptation. As predicted, approach versus avoidance arm movements affected both behavioral congruency effects and conflict adaptation: As compared to approach, avoidance movements elicited reduced congruency effects and increased conflict adaptation. These results are discussed in line with a possible underlying neuropsychological model.

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An important mechanism of our cognitive system is the allocation of resources to effectively deal with difficult, problematic, or novel situations, by up-regulating cognitive control. In a changing environment, being able to regulate cognitive control in a flexible manner helps us to respond adaptively to task demands. In addition to sustained, or *tonic*, cognitive control, dynamic adjustments of cognitive control consist of trial-by-trial adaptations of cognitive control as a function of previous trial difficulty due to conflict. This is called *conflict adaptation* and is thought to reflect temporary, or *phasic*, enhancements or reductions of cognitive control (Botvinick, Braver, Barch, Carter, & Cohen, 2001).

Paradigms such as the flanker task (Eriksen & Eriksen, 1974) were designed to examine cognitive control processes. In the flanker task, people have to indicate the direction of a central arrow, while adjacent arrows are in the same (congruent) or another (incongruent) direction. The strength of the congruency effect—entailing that congruent trials are responded to faster than incongruent trials—varies as a function of whether or not the previous trial contained a conflict: The congruency effect on the current trial is less strong after an incongruent trial than after a congruent trial (Gratton, Coles, & Donchin, 1992). This effect of the previous trial on current trial performance is an empirical indicator of conflict adaptation. Ample studies have since shown that conflict adaptation is a robust phenomenon that occurs across several tasks (Egner, 2008; Gratton et al., 1992; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002).

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Modulators of cognitive control

Recent research has investigated how affectively valenced stimuli or mood states may modulate conflict adaptation (for reviews, see Chiew & Braver, 2011; Dreisbach & Fischer, 2012). For example, positive reward signals have been shown to modulate conflict adaptation (van Steenbergen, Band, & Hommel, 2009), although the direction of this effect seems to depend on performance-contingency and the type of stimuli that is used to signal reward (e.g., Braem et al., 2013; Braem, Verguts, Roggeman, & Notebaert, 2012; Stürmer, Nigbur, Schacht, & Sommer, 2011). Furthermore, disentangling manipulations of affect (positive vs. negative) and arousal (high vs. low), several studies have shown that, irrespective of arousal, negative states result in enhanced conflict adaptation, as compared to positive states (Kuhbandner & Zehetleitner, 2011; van Steenbergen, Band, & Hommel, 2010; cf. van Steenbergen, Band, Hommel, Rombouts, & Nieuwenhuis, 2014; van Steenbergen, Booij, Band, Hommel, & van der Does, 2012). In some studies, arousal did not have any effect (van Steenbergen et al., 2010), whereas others have shown that high-arousing pictures, such as mutilated bodies, resulted in slower reaction times and reduced conflict adaptation (Padmala, Bauer, & Pessoa, 2011; cf. Fischer, Dreisbach, & Goschke, 2008). Kuhbandner and Zehetleitner (2011) have demonstrated independent modulation of affect and arousal on dynamic and sustained cognitive control, respectively, as was also confirmed by computer simulations showing independent modulation of related parameters in Botvinick et al.'s (2001) conflict-monitoring model.

To summarize, research has shown differential effects of rewards, mood states, and arousal. To date, no studies have been conducted on the influence of approach and avoidance motivational states on conflict adaptation. As we will argue below, for theoretical reasons, approach versus avoidance motivational states constitute an important modulator of both conflict adaptation and the congruency effect.

Approach–avoidance orientation

Approach and avoidance may be considered the two most fundamental motivational states (Elliot, 2008). Approach motivation helps to attain essential outcomes in the world including food, drinks, and partners. On the other hand, avoidance motivation prevents us from danger and negative outcomes. Their impact is documented across multiple domains. For instance, several studies illustrated the interplay between approach and avoidance movements and stimulus evaluation. Pull responses (approach) have been shown to be faster toward positive than toward negative stimuli, whereas push reactions (avoidance) have been shown to be faster for negative than for positive stimuli (Chen & Bargh, 1999). The reverse causality has also been shown. Stimuli viewed during an approach arm movement were evaluated more positively than stimuli viewed during an avoidance arm movement (Cacioppo, Priester, & Berntson, 1993; cf. Centerbar & Clore, 2006). According to Cacioppo and his colleagues, engaging in an approach arm movement provides body feedback associated with approaching positive stimuli, whereas engaging in an avoidance arm movement provides body feedback associated with avoiding negative stimuli (see also Förster & Strack, 1997, 1998). This theoretical assumption is based on the notion that over the course of a lifetime, arm flexion is repeatedly associated with acquiring or consuming desired objects (i.e., approach motivation), whereas arm extension is repeatedly associated with rejecting undesired objects (i.e., avoidance motivation).

However, approach and avoidance effects go beyond stimulus evaluations (Barsalou, 2008). For example, approach and avoidance have been argued to influence a corresponding motivational mindset or regulatory focus. According to Higgins (1999), individuals with a promotion focus are generally motivated by the presence and absence of positive outcomes, whereas the behavior of individuals in a prevention focus is motivated by the presence or absence of negative outcomes. These general foci have an influence on the regulation of people's behavior. Friedman and Förster (2000, 2005a) argued that approach and avoidance arm movements, triggering their corresponding foci, enhance creativity and analytic reasoning, respectively. An approach mindset seems to foster a heuristic processing style, enabling individuals to be more creative—to "think outside the box"—whereas an avoidance mindset fosters a systematic processing style enabling individuals to be more analytic (Friedman & Förster, 2000, 2005a).

Several other studies have suggested the role of arm movements in regulatory focus. Research has suggested that the intensity of pressure exerted through approach or avoidance arm movements functions as an indicator of motivational strength (Förster, Higgins, & Idson, 1998). Similarly, approach and avoidance arm movements directly influence motivation: Förster (2003) showed that participants engaging in an approach arm movement consumed more food than did individuals engaging in an avoidance arm movement. Taken together, all of these findings combined suggest that the arm movements activate their corresponding motivational system: Arm flexion activates a motivational system concerned with the processing of rewards, whereas arm extension activates a motivational system concerned with the processing of possible threats.

Approach–avoidance and sustained cognitive control

Avoidance bodily actions, as opposed to approach bodily actions, are habitually performed in situations that call for vigilance and controlled action. Therefore, the mere execution of an avoidance motor action may function as a subtle alert for difficult conditions (see Kahneman, 1973), which leads to an overall greater recruitment of resources that are usually required in this specific context. In contrast, performing an approach movement serves as a signal of safety and therefore indicates the absence of threat (Friedman & Förster, 2000). Mobilization of cognitive resources is then less needed, and cognitive control may be down-regulated on a general, tonic level.

Indeed, previous research has already shown the differential impacts of approach and avoidance motivational states in regulating resource allocation. In a series of studies, it was shown that avoidance orientation (induced by arm extension), relative to approach orientation (induced by arm flexion), enhanced sustained cognitive control, as measured by reduced congruency effects on a Stroop task and a task-switching paradigm (Koch, Holland, & van Knippenberg, 2008; see also Koch, Holland, Hengstler, & van Knippenberg, 2009; for alternative findings, see Friedman & Förster, 2005b). In another study, Koch and colleagues showed further evidence for a resources allocation account (Koch, 2008). On an initial cognitive control task, individuals in the avoidance condition performed better, but subsequently showed greater indications of resource depletion. Importantly, the effect of approach–avoidance state on the initial task was mediated by the degree of depletion, suggesting that superior performance in the avoidance condition was achieved by greater expenditure of cognitive resources. In the present research, we aimed to extend the findings of Koch and colleagues (2009; Koch et al., 2008) by showing that approach and avoidance motivational states may also modulate dynamic adjustments in cognitive control—that is, conflict adaptation.

Approach–avoidance and dynamic cognitive control

Besides a tonic process (cf. Kuhbandner & Zehetleitner, 2011), approach and avoidance states may alter conflict-driven resource allocation. Before explaining how this might work, it is important to note that conflict is associated with negative affect, signaling that conflict is an aversive event (Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013; Schouppe, de Houwer, Ridderinkhof, & Notebaert, 2012). Previous work has shown that individuals who are in an avoidant mindset are biased to conflicting (aversive) cues, whereas individuals who are in an approach mindset are less concerned with conflict and focus more on positive outcomes (Derryberry & Reed, 1994; Gomez & Gomez, 2002; Higgins & Tykocinski, 1992; Scholer, Stroessner, & Higgins, 2008; Shah, Higgins, & Friedman, 1998; Strachman & Gable, 2006). For example, Derryberry and Reed found that people with strong approach motivation were biased toward positive cues in a visual target detection task, whereas people with strong avoidance motivation were biased toward negative cues. Similarly, Gomez and Gomez showed that approach motivation (BAS) predicted the processing of positive (but not negative) emotional information, and avoidance motivation (BIS) predicted the processing of negative (but not positive) emotional information. Furthermore, research suggests that in an approach state, individuals are not only biased toward positive cues, but also retrieve such cues better; that is, positive information is processed more thoroughly. In an avoidant state, negative information is processed more thoroughly (Förster & Strack, 1997, 1998).

If being in an avoidant state biases individuals toward conflicting cues, and this information is processed more thoroughly, this might result in allocating more resources in response to conflicting signals—that is, a phasic, conflict-driven adaptation of cognitive control. Conversely, if in an approach state conflict processing diminishes, this should consequently weaken conflict adaptation.

Present research

Following the reasoning described above, we expected to find (1) enhanced conflict adaptation in the avoidance condition and reduced conflict adaptation in the approach condition, and (2) a replication of earlier findings (Koch et al., 2009; Koch et al., 2008) showing that avoidance leads to a smaller congruency effect than does approach. These ideas were tested in three studies. In the first study, we compared an approach state with an avoidant state. In the second study, we added a control condition to examine the separate contributions of approach and avoidance motivation to the hypothesized effects. Finally, in the third study, we employed a flanker task that allowed us to control for feature repetitions and contingency confounds (Hommel, Proctor, & Vu, 2004; Mayr, 2004; Nieuwenhuis et al., 2006; Schmidt, 2013; Schmidt & de Houwer, 2011) that could have affected the indices of conflict adaptation in the former studies. In addition, we included some additional questions, to measure effort of arm movement and mood. Moreover, we included a scale to measure promotion–prevention orientation, intended as a manipulation check of the arm movement manipulation. Throughout the three studies, we employed a manipulation of approach and avoidance states by instructing participants to make an approach or avoidance motor action (Cacioppo et al., 1993; Koch et al., 2008). More specifically, participants were asked to engage in either arm flexion (approach) or arm extension (avoidance) while performing a flanker task.

Study 1

Methods

Participants A total of 71 students (61 females, ten males) from Radboud University Nijmegen participated in this study. The mean age of the participants was 19.8 years (range 18 to 27 years). In return for credits, participants were assigned to either the approach condition or the avoidance condition.

Procedure Instructions were given on a computer screen. While participants performed an approach or avoidance motor action with their nondominant hand, they responded to a flanker task using their dominant hand (Eriksen & Eriksen, 1974). Using their nondominant hand, participants in the approach condition pressed a foam ball against the bottom of the table to elicit and maintain isometric flexor contraction of the arms, whereas in the avoidance condition they pressed the foam ball against the top of the table to elicit and maintain isometric extensor contraction (cf. Cacioppo et al., 1993; Koch et al., 2008). In Fig. 1, photographs illustrate the arm positions used to manipulate approach and avoidance. The flanker stimuli consisted of a row of five white arrows pointing to the left or the right against a black background. Participants were instructed to make quick and accurate responses on the keyboard using their dominant hand to indicate the direction of the central arrow, while the adjacent arrows were in the same (congruent) or in the opposite (incongruent) direction. Participants performed 12 practice trials. In order to reduce between-subjects error noise due to a randomized trial order, instead of using a fully randomized order for each participant, we created two pseudorandomized orders of 66 test trials that were divided into two blocks of 33 trials (the first trial of each block could not be used, because it had no previous trial).[1] Within these two orders, all four trial types (cC, iC, cI, and iI) were randomly distributed over the 66 trials, with the restriction that they had to be administered equally often, and the same trial type should not be presented more than three times in a row. Each trial started with a fixation cross displayed for 1,000 ms, followed by the flanker stimulus that was displayed until a response was given. In the practice phase, upon an error, feedback was provided by showing a red cross for 400 ms.

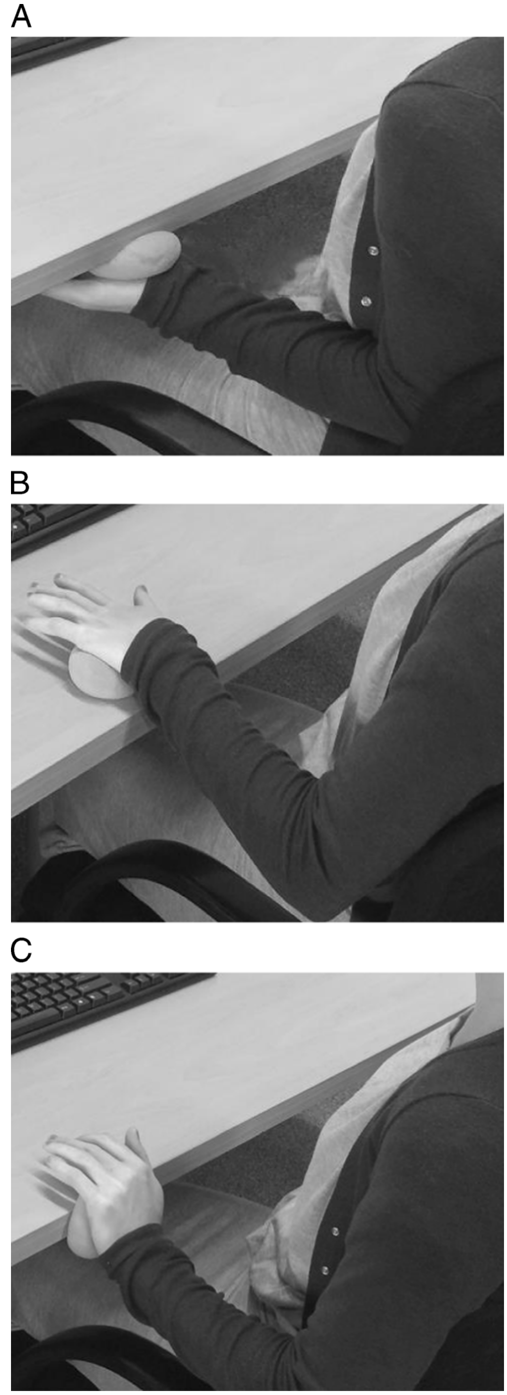

Fig. 1 (**a**) Photograph of the approach induction in Studies 1, 2, and 3. (**b**) Photograph of the avoidance induction in Studies 1 and 2. (**c**) Photograph of the avoidance induction in Study 3

Data analysis We analyzed the reaction times (RTs) of correct responses for test trials using a mixed design, with Previous Trial (c vs. i) and Current Trial (C vs. I) as within-subjects factors and Motivational State (approach vs. avoidance) as a between-subjects factor. Error trials (3.7%) and trials with RTs more than 3 *SD*s above or below the individual condition-specific mean (0.9%) were excluded from the analysis. We

[1] We refrained from using a higher number of trials because (1) we were not sure about the duration of the effect of arm movement—since the arm movement had to be performed during the task, one can imagine that the effect of the arm manipulation might wear off after some time; and (2) some studies have suggested that conflict adaptation effects disappear quickly over time (Mayr & Awh, 2008; van Steenbergen, Haasnoot, Bocanegra, Berretty, & Hommel, 2014 Manuscript submitted for publication), so using a low number of trials per condition might help to measure the effect that we aimed to investigate here. A previous study showing effects of dysphoric mood on conflict adaptation had also used only 64 trials in total (van Steenbergen, Booij, et al., 2012).

also removed one participant who had a much higher general RT than the average (6 *SD*s above the sample mean), and one participant who made many more errors on inconsistent trials than the average (6 *SD*s above the sample mean).[2]

Results

The results showed a congruency effect: The main effect of current trial was significant, indicating that performance on the flanker task was faster on congruent (383 ms) than on incongruent (429 ms) trials, $F(1, 69)=271.08$, $p<.001$, $\eta^2=.80$. The interaction between previous trial and current trial was also significant, indicating a conflict adaptation effect, $F(1, 69)=4.33$, $p=.04$, $\eta^2=.06$. The conflict adaptation effect entails that the current RT difference (I – C) was smaller when the previous trial was incongruent (i) than when it was congruent (c). Most importantly, both the congruency and conflict adaptation effects interacted with motivational state, as we will describe below. See Table 1 for the full range of condition means.

We found a Previous Trial × Current Trial × Motivational State interaction, $F(1, 69)=6.04$, $p=.02$, $\eta^2=.08$ (see Fig. 2a). To understand the nature of this interaction, we analyzed the interaction effects of previous trial and current trial separately for approach and avoidant states. This revealed a strong Previous Trial × Current Trial interaction in the avoidance condition, $F(1, 34)=11.89$, $p<.01$, $\eta^2=.26$, whereas this effect was absent for the approach condition, $F(1, 35)<1$.

We also found a Current Trial × Motivational State interaction, $F(1, 69)=6.58$, $p=.01$, $\eta^2=.09$ (see Fig. 2b). Although the effect of current trial—that is, the congruency effect—was significant in both the approach and avoidance conditions (*p*s <.001), the interaction meant that the congruency effect was significantly smaller in the avoidance condition (39 ms) than in the approach condition (53 ms).

Notably, we observed no significant correlation between the congruency effect and the conflict adaptation effect, $r(71)=-.07$, $p=.56$. We also tested the unique effect of motivational state on the congruency effect with the conflict adaptation effect partialed out, as well as the effect of motivational state on conflict adaptation with the congruency effect partialed out. To do this, we first computed a congruency score (I – C) and a conflict adaptation score [(iI – iC) – (cI – cC)]. Subsequently, we conducted an analysis of covariance (ANCOVA), with congruency score as the dependent variable (DV), Motivational State as the between-subjects factor, and conflict adaptation score as a covariate. The results indicated that the effect of motivational state on the congruency effect remained significant in this analysis, $F(1, 71)=6.13$, $p=.02$, $\eta^2=.08$. Similarly, when we switched the roles of congruency effect (from DV to covariate) and conflict adaptation effect (from covariate to DV), again the effect of motivational state remained significant, $F(1, 71)=5.60$, $p=.02$, $\eta^2=.08$.

Table 1 Mean reaction times (RTs, in milliseconds) and *SE*s for each trial type in the three reported studies

Study	Condition	Congruency (*N* – 1)	Congruency (*N*)	Mean RT	*SE*
1	Approach	Congruent	Congruent	380.74	6.74
			Incongruent	432.91	8.31
		Incongruent	Congruent	382.58	7.18
			Incongruent	436.37	7.80
	Avoidance	Congruent	Congruent	383.69	6.83
			Incongruent	432.10	8.43
		Incongruent	Congruent	386.43	7.28
			Incongruent	415.41	7.91
2	Approach	Congruent	Congruent	385.77	7.93
			Incongruent	441.96	9.76
		Incongruent	Congruent	391.33	7.59
			Incongruent	447.33	9.72
	Control	Congruent	Congruent	395.99	8.07
			Incongruent	445.51	9.94
		Incongruent	Congruent	402.63	7.73
			Incongruent	441.30	9.89
	Avoidance	Congruent	Congruent	394.86	7.93
			Incongruent	441.13	9.76
		Incongruent	Congruent	398.46	7.59
			Incongruent	420.39	9.72
3	Approach	Congruent	Congruent	478.19	10.90
			Incongruent	519.41	9.66
		Incongruent	Congruent	480.82	10.61
			Incongruent	531.82	9.77
	Avoidance	Congruent	Congruent	493.36	10.67
			Incongruent	535.89	9.45
		Incongruent	Congruent	498.95	10.38
			Incongruent	516.37	9.56

Study 2

In Study 1, we compared an approach state with an avoidant state. The results revealed strong conflict adaptation in the avoidance relative to the approach condition. In addition, we replicated previous research by finding a smaller congruency effect for avoidance than for approach (Koch et al., 2008). In Study 2, we added a control condition, to examine the separate

[2] The interaction between previous trial and current trial became nonsignificant ($p=.204$) when these two outliers remained included in the data set. Also, the three-way interaction between previous trial, current trial, and motivational state became nonsignificant ($p=.108$).

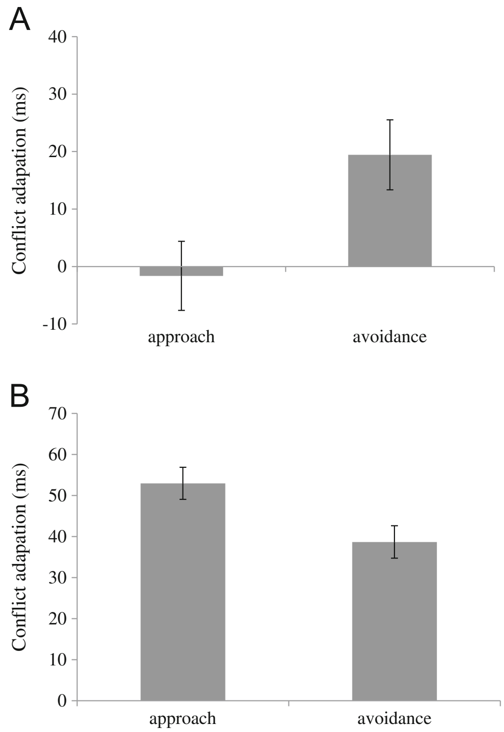

Fig. 2 (**a**) Mean reaction times (in milliseconds) representing the conflict adaptation scores of Study 1, (cI – cC) – (iI – iC). Error bars represent *SE*s. (**b**) Mean reaction times representing the congruency scores of Study 1, I – C. Error bars represent *SE*s

contributions of approach and avoidance motivation to these effects.

Methods

Participants A group of 86 students (76 females, ten males) from Radboud University Nijmegen participated in this study. The mean age of the participants was 21.7 years (range 18 to 35 years). We added a control condition to examine the differential effects of approach and avoidance motor actions. In return for credits, participants were assigned to the approach condition, the control condition, or the avoidance condition.

Procedure The procedure of Study 2 was exactly the same as in Study 1, with the addition of a control condition. In the control condition, people had to rest their nondominant hand on their lap (i.e., they did not engage in arm flexion or extension), whereas in the other conditions they had to perform the respective arm movements.

Data analysis We used the same kind of analyses as in Study 1. Error trials (3.4%) and trials with RTs more than 3 *SD*s above or below the individual condition-specific mean (0.6%) were excluded from the analysis. The data revealed no between-subjects outliers.

Results

The results showed the congruency effect: Performance on the flanker task was faster on congruent (395 ms) than on incongruent (439 ms) trials, $F(1, 83)=194.08, p<.001, \eta^2=.70$. The interaction between previous trial and current trial was again significant, indicating a conflict adaptation effect, $F(1, 83)=13.26, p<.001, \eta^2=.14$. See Table 1 for the full range of condition means.

Most importantly, the results of Study 2 also showed a Previous Trial × Current Trial × Motivational State interaction, $F(2, 83)=4.72, p=.01, \eta^2=.10$ (see Fig. 3a). We found a conflict adaptation effect for the avoidance condition, $F(1, 28)=14.38, p=.001, \eta^2=.34$, as well as for the control condition, $F(1, 27)=10.84, p<.01, \eta^2=.29$. No evidence of such an effect was observed for the approach condition, $F(1, 28)<1$. LSD pairwise comparisons on the conflict adaptation scores showed that avoidance (24 ms) differed from approach (0 ms), $p<.01$, 95% CI [8.48, 39.84], and marginally significantly from control (11 ms), $p=.09$, 95% CI [–2.32, 29.32]. Control did not differ from approach, $p=.18$.

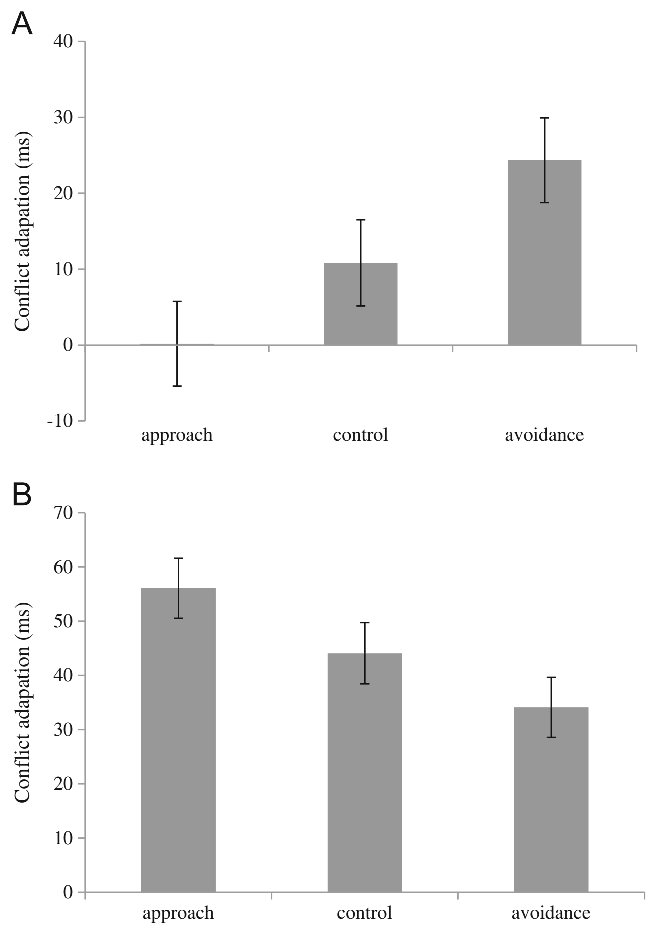

Fig. 3 (**a**) Mean reaction times (in milliseconds) representing the conflict adaptation scores of Study 2, (cI – cC) – (iI – iC). Error bars represent *SE*s. (**b**) Mean reaction times representing the congruency scores of Study 2, I – C. Error bars represent *SE*s

We also found a Current Trial × Motivational State interaction, $F(2, 83)=3.96$, $p=.02$, $\eta^2=.09$ (see Fig. 3b). All simple effects were significant for each level of motivational state (ps <.001). LSD pairwise comparisons on the congruency scores showed that avoidance (34 ms) differed from approach (56 ms), $p<.01$, 95% CI [–37.56, –6.44]. Control (44 ms) did not differ from either approach or avoidance, ps=.13 and .21, respectively.

Again, we found no significant correlation between the congruency effect and the conflict adaptation effect, $r(86)=.03$, $p=.82$. As in Study 1, we tested the unique effect of motivational state on the congruency effect with the conflict adaptation effect partialed out, as well as the effect of motivational state on conflict adaptation with the congruency effect partialed out. The results of the ANCOVAs, indicated that the effect of motivational state on the congruency effect remained significant, $F(2, 86)=4.67$, $p=.01$, $\eta^2=.10$, as well as the effect of motivational state on the conflict adaptation effect, $F(2, 86)=5.43$, $p=.01$, $\eta^2=.12$.

Reanalysis of Studies 1 and 2

In Studies 1 and 2, we consistently found an effect of motivational state on both sustained and dynamic cognitive control. Furthermore, motivational state seemed to independently influence these two forms of control regulations.

An important limitation of Studies 1 and 2, and of many other studies in the domain of conflict adaptation, was the potential confound of repetition priming. Some studies have shown that conflict adaptation effects can be accounted for entirely by repetition-priming effects (e.g., Mayr, 2004; Nieuwenhuis et al., 2006). Repetitions occur on 50% of the cC and iI trials, but on none of the iC or cI trials. The typical decreased RTs on cC and iI trials evident in sequential effects might thus (partly) be driven by repetition priming rather than by conflict adaptation.

To address the issue of repetition effects, at least to some extent, we ran an analysis that excluded all complete-repetition trials—that is, all trials in which the stimulus at trial $N+1$ was exactly the same as the stimulus at trial N (see Mayr, 2004). Because removing all complete-repetition trials reduced the power of the tests, we created a new data file encompassing the data from Studies 1 and 2 (without the control condition). We subjected these data to a repeated measures analysis of variance (ANOVA) with Previous Trial (c vs. i) and Current Trial (C vs. I) as within-subjects factors, and Motivational State (approach vs. avoidance) and Study (1 vs. 2) as between-subjects factors. Crucially, as is shown in Table 2, the influence of motivational state on both the congruency effect and the conflict adaptation effect remained significant after excluding all complete stimulus repetitions.

Although this is encouraging, using a design with four stimuli and two response options did not allow us to exclude different alternative explanations in terms of feature integration, which predicts that complete alternations (all remaining cC and iI trials) would be faster than partial repetitions (all cI and iC trials), due to feature binding effects (Hommel et al., 2004). Therefore, in Study 3, we used an optimized design (cf. Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014 Manuscript under review) in which we only presented complete alternations for all sequential trial types (cf. Ullsperger, Bylsma, & Botvinick, 2005), while at the same time correcting for the more recently discussed confounds in terms of contingency biases (Schmidt, 2013; Schmidt & de Houwer, 2011). We also included some additional questions, to measure effort of arm movement and mood. Moreover, we included a scale to measure promotion–prevention orientation, which was intended as a manipulation check of the arm movements that we manipulated.

Table 2 Results of the meta-analysis over the first two studies, examining the influence of motivational orientation on both the congruency effect and the conflict adaptation effect, excluding complete-repetition trials

Source	F	p	η^2
Congruency (N) × Orientation	6.38	.01	.05
Congruency (N) × Congruency (N – 1) × Orientation	4.55	.04	.04
Congruency (N) × Study	0.20	.66	.00
Congruency (N) × Congruency (N – 1) × Study	5.19	.02	.04
Congruency (N) × Study × Orientation	1.09	.30	.01
Congruency (N) × Congruency (N – 1) × Study × Orientation	1.93	.17	.02

Study 3

Method

Participants A total of 96 students (73 females, 23 males) from Radboud University Nijmegen participated in this study. The mean age of participants was 20.9 years (range 18 to 29 years). In return for credits, participants were assigned to either the approach condition or the avoidance condition.

Procedure Instructions were given on a computer screen. While participants performed an approach or avoidance motor action with their nondominant hand, they responded to a flanker task using their dominant hand (Eriksen & Eriksen, 1974). Similar to Studies 1 and 2, using their nondominant hand, participants in the approach condition pressed a foam ball against the bottom of the table to elicit and maintain isometric arm flexor contraction (Fig. 1a). We slightly changed the position concerning the avoidance condition. In this condition, also using their nondominant hand, participants pressed a foam ball against the frontal side of the table to elicit and maintain isometric arm extensor contraction (Fig. 1c). In our view, the latter position even more strongly converges with avoidance, since it more clearly reflects a "pushing something away" gesture. The flanker stimuli consisted of a row of five black arrows against a white background. Participants were instructed to make quick and accurate responses on the keyboard using their dominant hand to indicate the direction of the central arrow, whereas the adjacent arrows were in the same (congruent) or in another (incongruent) direction. The responses keys were [i], [j], [k], and [m]. The arrows could point in one of four directions: up, down, left, or right. In order to control for potential contingency bias effects (Schmidt, 2013; Schmidt & de Houwer, 2011), we included only four out of the 12 possible combinations of incongruent trials, so that four trial types were used (equally often) for both the congruent and incongruent trials (cf. Manuscript under review). We created two different orders of 101 trials, in which all four trial types (cC, cI, iC, and iI) were randomized with the restriction that they had to be administered equally often, and the same trial type was presented not more than three times in a row. Finally, stimulus and feature repetitions were controlled by only allowing complete feature alternations. For example, a congruent trial with all of the arrows facing upward could only be followed by a next stimulus that did not include any upward-facing arrows—for example, a stimulus with flankers facing left and the central target facing down. The trial after that could only display a stimulus that did not have any arrows facing left and/or down, and so on.

Participants performed a block of 16 practice trials. The practice block was repeated until the participants' performance accuracy reached 85% correct answers, or until the block was run for a maximum number of four times. Subsequently, participants completed 101 experimental trials while engaging in an approach or avoidance arm movement. Each trial started with a blank screen for 1,000 ms, followed by the flanker stimulus, which was displayed until a response was given. In the practice phase, upon an error, feedback was provided by showing a red cross for 400 ms.

After the experimental phase of the flanker task, participants were asked once more to engage in the condition-specific arm movement, this time while answering a questionnaire about proverbs (RFQ-short; van Stekelenburg & Klandermans, 2003). The questionnaire contained 14 items: seven promotion-focused items (e.g., "Nothing ventured, nothing gained") and seven prevention-focused items (e.g., "Better safe than sorry"). Participants were asked to answer the following question for each of the items on a 7-point Likert scale: "To what extent does this saying apply to you as a person. Don't think too long about your answer, what comes to mind first often is the best answer." In a pilot study, we found that this scale reliably differentiated between motivation elicited by approach and avoidance arm movements.[3]

Finally, participants were asked to indicate, on a scale from 1 to 100, the amount of effort that they experienced while engaging in the condition-specific arm movement (1 = *no effort*, 100 = *very much effort*), and their current mood state (1 = *negative mood state*, 100 = *positive mood state*).

Data analysis We used the same kind of analyses as in Studies 1 and 2. Error trials (1.6%) and trials with RTs more than 3 *SD*s above or below the individual condition-specific mean (1.8%) were excluded from the analysis. We also removed two participants who had a higher general RT than the average (>3 *SD*s above the sample mean), and another two participants who made more errors on inconsistent trials than the average (>3 *SD*s above the sample mean).[4]

Results

Manipulation check On the basis of the results of a pilot study, factor analysis was used to identify and compute a score for the factor underlying the short version of the RFQ (see note 3). First, we observed that all items correlated at least .3 with at least one other item, suggesting reasonable factorability. Second, the Kaiser–Meyer–Olkin measure of sampling adequacy was .73, which was above the commonly recommended value of .6, and Bartlett's test of sphericity was significant [$\chi^2(91)=291.87$, $p<.001$]. The diagonals of the anti-image correlation matrix were also all over .5. Finally, the communalities were all above .3, further confirming that each item shared some common variance with the other items. Given these overall indicators, factor analysis was deemed to be suitable with all 14 items.

[3] The RFQ-short was pilot tested in a different session with different participants (N=55). The α for the promotion scale was .57, and that for the prevention scale was .59. Both αs are lower than the generally accepted minimal reliability of .70. Therefore, instead of using these a priori constructs, all items of the RFQ scale were subjected to an exploratory principal component analysis. The results of this analysis revealed a single-factor solution (additional factors proved to be uninterpretable), explaining 18% of the variance. This factor was labeled Promotion Versus Prevention, because promotion-focused items loaded positively on this factor, whereas prevention-focused items loaded negatively on it. Subsequently, we subjected this Promotion Versus Prevention factor score to an ANOVA with Motivational State as a between-subjects factor. The results revealed a significant effect of motivational state, $F(1, 55)=7.12$, $p=.01$, $\eta^2=.12$: Participants in the approach condition responded more in line with a promotion focus (M=.33), whereas those in the avoidance condition responded more in line with a prevention focus (M=–.35), thus corroborating the intended motivational implications of the approach and avoidance arm movements. We also used this factor-analytic approach for our manipulation check in Study 3.

[4] The pattern of significant and nonsignificant results did not change when these four participants were included in the analysis.

Principal component analysis with listwise deletion revealed a single-factor solution (additional factors proved difficult to interpret), explaining 26% of the variance. Promotion-focused items loaded positively on this factor, whereas prevention-focused items loaded negatively on it. We computed the factor score for this factor and added it to the data file, so that each participant had such a score. To attribute meaning to this factor score, a positive score entailed responding more in line with a promotion focus, whereas a negative score entailed responding more in line with a prevention focus. Subsequently, this factor score was subjected to an ANOVA, with Motivational State as a between-subjects factor. The results revealed a significant effect of motivational state, $F(1, 92)=4.88$, $p=.03$, $\eta^2=.05$: Participants in an approach state responded more in line with a promotion focus ($M=.23$), whereas participants in an avoidance state responded more in line with a prevention focus ($M=-.22$).

Flanker task The results showed a congruency effect: The main effect of current trial was significant, indicating that performance on the flanker task was faster on congruent (488 ms) than on incongruent (526 ms) trials, $F(1, 90)=161.81$, $p<.001$, $\eta^2=.64$. The interaction between previous trial and current trial was not significant, $p>.13$. However, both effects did interact with motivational state, as we will describe below. See Table 1 for the full range of condition means.

We found a Previous Trial × Current Trial × Motivational State interaction, $F(1, 90)=11.63$, $p<.002$, $\eta^2=.11$ (see Fig. 4a). To illustrate the nature of this interaction, we analyzed the interaction effects of previous trial and current trial separately for the experimental conditions. We found a strong Previous Trial×Current Trial interaction in the avoidance condition, $F(1, 46)=9.47$, $p<.01$, $\eta^2=.17$, whereas this effect was absent for the approach condition, $F(1, 44)=2.60$, $p>.11$, $\eta^2=.06$.

We also found a Current Trial × Motivational State interaction, $F(1, 90)=7.28$, $p=.008$, $\eta^2=.08$ (see Fig. 4b). Although the effect of current trial—that is, the congruency effect—was significant in both the approach and avoidance conditions (ps<.001), the congruency effect was significantly smaller in the avoidance condition (30 ms) than in the approach condition (46 ms).

In contrast to Studies 1 and 2, the results now showed a significant negative correlation between the congruency effect and the conflict adaptation effect, $r(92)=-.22$, $p=.03$. We again tested the unique effect of motivational state on the congruency effect with the conflict adaptation effect partialed out, as well as the effect of motivational state on conflict adaptation with the congruency effect partialed out. The results of the ANCOVAs indicated that the effect of motivational state on the congruency effect remained significant, $F(1, 92)=4.35$, $p=.04$, $\eta^2=.05$, as well as the effect of motivational state on the conflict adaptation effect, $F(1, 92)=8.53$, $p=.004$, $\eta^2=.09$.

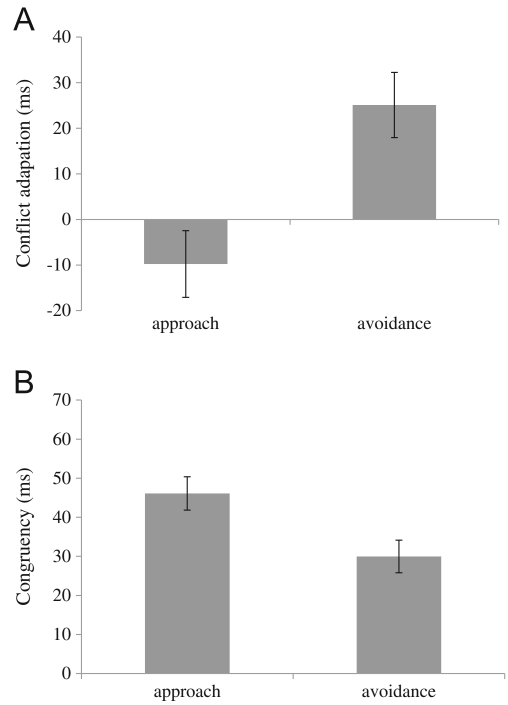

Fig. 4 (**a**) Mean reaction times (in milliseconds) representing the conflict adaptation scores of Study 3, (cI – cC) – (iI – iC). Error bars represent *SE*s. (**b**) Mean reaction times representing the congruency scores of Study 3, I – C. Error bars represent *SE*s

No significant differences in mood ($M_{appr}=74$, $M_{avoid}=73$) or experienced effort of the arm position ($M_{appr}=58$, $M_{avoid}=51$) were obtained between conditions, and adjusting for these variables as covariates in the reported analyses did not change the pattern of significant and nonsignificant results reported above, suggesting that these variables did not mediate the effects of motivational state on cognitive control.

Discussion

In the present research, we investigated the influence of approach and avoidance body movements on dynamic and sustained control, as measured by the conflict adaptation effect and the congruency effect, respectively. This research was the first to show an effect of motivational orientation on conflict adaptation. In three studies, we showed that both the congruency effect and the conflict adaptation effect differed between an approach motivational state and an avoidance motivational state. For the congruency effect, avoidance differed from approach, whereas the control condition differed from neither approach nor avoidance. Concerning conflict adaptation, avoidance differed from approach and, marginally, from control, whereas the latter two did not differ significantly (even though the conflict adaptation effect was not significant in the approach condition, whereas it was reliable in the control condition). These effects were replicated in Study 3, where we controlled for feature binding effects, contingency biases, and possible alternative moderators such as effort and mood. Although more research will be necessary to differentiate between the different possible processes, we think that our reasoning, entailing that motivational orientation influences the attention for conflict signals, and thereby influences the regulation of control, is the most parsimonious explanation of the present findings.

Our work seems at least partially in line with previous work on the influence of mood or affective states on conflict adaptation (e.g., van Steenbergen et al., 2009, 2010). The theoretical framework for this link between affective states and modulation of cognitive control is based on the aversive nature of demand (see Botvinick, 2007; Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013). That is, positive affect might undo or reduce the aversive state triggered by a demand, whereas negative mood states might intensify it (see Fredrickson, Mancuso, Branigan, & Tugade, 2000). However, our findings cannot be explained by differences in mood states, given that the previous research using the manipulation of approach and avoidance motivational orientations (e.g., Cretenet & Dru, 2004; Förster & Strack, 1998; Friedman & Förster, 2000; Koch, 2008; Nussinson, Häfner, Seibt, Strack, & Trope, 2012; van den Bergh, Schmitt, Dewitte, & Warlop, 2009; van Prooijen, Karremans, & van Beest, 2006) has never consistently found any relation between the corresponding arm movements and mood states. In Study 3 of the present article, we also directly tested the influence of mood and found neither a significant effect of mood nor a different behavioral pattern when adding mood scores as a covariate.

Still, approach and avoidance orientations could change the implicit evaluative processing of conflict. Previous work has shown that approach and avoidance arm movements change the evaluation of neutral objects that are evaluated at the time of the movements (Cacioppo et al., 1993). Approach and avoidance motor actions might reduce or increase, respectively, the negativity of the demand, and consequently, modulate the conflict-driven phasic effort mobilization (cf. Braem et al., 2012; van Steenbergen et al., 2009). However, the latter process is unlikely, because approach and avoidance arm movements seem to have different impacts on neutral and ambiguous objects than on valenced objects. In fact, studies have shown that the performance of an avoidance arm movement, in conjunction with evaluating a mildly negative object, causes that object to become more positive rather than negative (Centerbar & Clore, 2006). The attitudinal impact of approach–avoidance action thus reflects its situated meaning, which depends on the valence of the stimuli being approached or avoided. Given that conflict is often negatively evaluated, this may trigger a more positive affective state, which is unlikely to enhance conflict adaptation effects. Therefore, this explanation is also not compatible with the present results.

The results with regard to the congruency effect are fully in line with previous work on the influence of approach and avoidance motivational orientation on cognitive control (Koch et al., 2009; Koch et al., 2008). Participants in the avoidance condition were faster (or made fewer errors) on incongruent than on congruent trials. Interestingly, in the present research we found evidence that motivational orientation seemingly independently influences both sustained cognitive control (i.e., the congruency effect) and dynamic cognitive control (i.e., the conflict adaptation effect), because both effects remained significant when controlling for the other.

It is notable that—in the avoidance as compared to the approach condition—our findings showed reduced congruency effects and increased conflict adaptation effects at the same time. Given that previous studies using affect inductions have shown that both effects can be modulated independently, we assume that these effects are driven by two independent sources. As we argued above, conflict adaptation effects may be influenced by sensitivity to the aversive nature of conflict. On the other hand, sustained control might be driven by the motivational requirements of the situation, which associate avoidance movements with more mobilized cognitive resources, in general. Such independent modulation is also consistent with simulation work that has shown dissociable mechanisms of sustained versus dynamic control in the conflict-monitoring model (Kuhbandner & Zehetleitner, 2011). However, this is not to say that congruency effects and conflict adaptation effects are always independent, since studies have shown that both effects can be increased when a common source, such as conflict strength, is manipulated (e.g., Forster, Carter, Cohen, & Cho, 2011; Wendt, Kiesel, Geringswald, Purmann, & Fischer, 2013; cf. Scherbaum, Fischer, Dshemuchadse, & Goschke, 2011). However, in line with cumulating evidence (van Steenbergen et al., 2009; van Steenbergen, Band, & Hommel, 2012; van Steenbergen, Band, et al., 2014), the increased adaptation effects in the context of reduced interference effects in our study show that conflict strength in mere cognitive terms is not sufficient to account for all types of modulation, and suggests that the affective evaluation of conflict is likely an important source of control adaptation, as well.

Although the present article presents behavioral studies, it will be worthwhile to ponder the underlying neuropsychological mechanism involved. It is conceivable that approach and avoidance systems directly modulate the lateral prefrontal cortex (PFC), explaining the differential effects of approach and avoidance on sustained cognitive control. Avoidance seems to be associated with right hemispheric PFC activity, whereas approach is associated with left hemispheric PFC activity (Berkman & Lieberman, 2009; Rutherford & Lindell, 2011). Enhanced activity in the right hemispheric

PFC is linked with enhanced attention, especially in supporting responsivity to environmental events—that is, conflicting signals (Pribram & McGuinness, 1975; cf. Heilman & Van Den Abell, 1980).

More recently, several neuroimaging studies have reported right PFC involvement in conflict adaptation (e.g., Egner, 2011; Egner & Hirsch, 2005; Kerns et al., 2004), providing more support for the possibility of modulation of cognitive control via motivational states. The idea of conflict-driven resource allocation in avoidance might be traced back to levels of anterior cingulate cortex (ACC) activity. If being in an avoidant state biases individuals toward conflicting cues (e.g., Gomez & Gomez, 2002), and this information is processed more thoroughly (Förster & Strack, 1997, 1998), this might result in maintaining higher levels of ACC activity directly after a conflicting event. This reasoning is based on research investigating the error-related negativity (ERN), hypothesized to originate from the ACC. It has been shown that negative affect is associated with amplified ERNs, whereas positive affect is related to reduced ERNs (e.g., Luu, Collins, & Tucker, 2000; Wiswede, Münte, Krämer, & Rüsseler, 2009). Similarly, the ACC activity during *correct* conflict trials might drive the regulation of dynamic cognitive control (cf. van Steenbergen, Band, et al., 2012; van Steenbergen, Band, et al., 2014). If the avoidance state indeed amplifies the ACC response to conflicting cues, it follows that it should also strengthen behavioral adaptations to cognitive conflict—that is, a phasic, conflict-driven adaptation of cognitive control. Conversely, being in an approach state might inhibit ACC activity in response to conflicting signals, and thereby decrease conflict monitoring directly following conflict (cf. Wiswede et al., 2009). If conflict processing diminishes in an approach state, this should consequently weaken behavioral adaptation.

One limitation of the present research is that our conclusions are based on behavioral data. It will therefore be interesting to investigate the neural mechanisms underlying the present effects in future studies. For example, using electroencephalography, one could test the differential effects of motivational orientation on the strength of conflict-induced ACC activation (see van Steenbergen, Band, et al., 2012). More precisely, ongoing fronto-central theta oscillations induced by previous conflict may sustain longer in an avoidance state than in an approach state, ostensibly reflecting ACC modulation. Furthermore, using fMRI, future studies should clarify which specific brain regions alter cognitive control processes in response to the current motivational state of an individual, as well as their respective roles. For instance, it is conceivable that avoidance motivational orientation might increase activity in the (rostral) ACC (van Steenbergen, Band, et al., 2014) and/or functional connectivity between the ACC and PFC.

To conclude, we have been the first to show the influence of approach–avoidance body movements on the regulation of sustained and dynamic adaptation of cognitive control. To keep our actions in line with our internal goals and intentions, our cognitive system is regulated by our current motivational state while it processes the information of salient environmental cues. As compared to approach, avoidance was associated with a reduced congruency effect and an increased conflict adaptation effect. Our results suggest that approach and avoidance motivational orientations differently and independently influence both sustained and dynamic cognitive control.

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