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ORIGINAL ARTICLE

Conflict modification: predictable production of congruent situations facilitates responding in a stroop task

Constantin Schmidts[1] · **Anna Foerster**[1] · **Wilfried Kunde**[1]

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Abstract

Humans cope with cognitive conflict in various ways, such as focusing on task-relevant instead of task-irrelevant information or avoiding situations where conflict is likely. These adaptations to conflict resemble those used to cope with negative affect. We examined whether situation modification, a strategy derived from the extended process model of emotion regulation, may influence responding in cognitive conflict tasks. This should be evident by a facilitation of actions that consistently modify situations towards congruent (positive) situations rather than to incongruent (negative) situations. In four experiments, participants modified stimuli in a color-word Stroop task towards congruent or incongruent stimuli of (un)predictable identity. A modification effect emerged insofar as participants were faster when they foreseeably produced congruent stimuli of predictable identity than when they produced incongruent stimuli or stimuli of unpredictable identity. Our results add to the body of evidence connecting affect and cognitive conflict, and reveal a constraint when using situation modification as a means to regulate cognitive conflict.

Introduction

Cognitive conflict occurs when the environment suggests mutually mismatching behavioral options. For example, when standing at a pedestrian crossing, a red light may suggest waiting, while observing other people crossing the road may suggest going. To model such situations in the lab, researchers use conflict tasks, such as the Stroop task (Stroop, 1935). Humans can cope with conflicts in various ways. For instance, observers try to ignore potentially conflicting information and focus on currently relevant information instead (Egner, 2017; Wendt, Luna-Rodriguez, & Jacobsen, 2012). Likewise, agents tend to avoid situations that they experienced to be conflict-laden (Dignath, Kiesel, & Eder, 2015; Schouppe, De Houwer, Ridderinkhof, & Notebaert, 2012).

Such means to cope with conflict remind of means to cope with negative affect. Gross (1998, 2015) proposed five ways to regulate aversive states along the timeline of an emotional event: people tend to (1) avoid negative stimulation, or try to (2) modify, (3) ignore, or (4) reinterpret it, or (5) inhibit the expression of affect. Avoiding conflict-laden stimulation (Dignath et al., 2015) or directing attention away from it (Wendt et al., 2012) corresponds to the emotion regulation strategies (1) and (3). This apparent similarity of conflict regulation and emotion regulation is probably not coincidental. Cognitive conflict presumably comes with negative affect (Botvinick, 2007; Dreisbach & Fischer, 2012; Saunders, Milyavskaya, & Inzlicht, 2015). Consequently, processes that handle conflict could be triggered by conflict-associated negative affect. Furthermore, approaches to regulate negative stimulation, such as ignoring it, or escaping it if possible, could also come into action for handling conflict-inducing stimulation.

Given this apparent similarity, we aimed to test whether another emotion regulation strategy, situation modification, could play a role in coping with cognitive conflict. Situation modification means that humans are prone to choose actions that alter a currently negative situation towards a more positive situation. Whereas most studies look at explicitly instructed emotion regulation, those processes can also work implicitly (Gyurak, Gross, & Etkin, 2011). In the updated version of the extended process model of emotion regulation, Gross (2015) assumes that perceiving the environment as positive or negative triggers an "action impulse" that has "the aim of addressing the gap between the perceived state of the world and the desired state of the

✉ Constantin Schmidts
constantin.schmidts@uni-wuerzburg.de

[1] Department of Psychology III, University of Würzburg, Röntgenring 11, 97070 Würzburg, Germany

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world" (p. 10). We assume that the desired state of the world for most people means relatively more positive than negative affect, so conflict situations should trigger action impulses that decrease the negative affect that they cause. We suggest that situation modification processes are at play when people are asked to modify the environment in a way that predictably changes its affective impact. Actions that foreseeably change a given negative situation into a more positive one should be facilitated as compared to actions that foreseeably change a given positive situation to a more negative one. For example, a currently requested action such as picking up the receiver of a ringing telephone should be generated more instantaneously when doing so terminates a conflict-laden communication and starts a pleasant one instead, rather than the other way round, when it terminates a pleasant communication for a conflict-laden one. Assuming that incongruency, novelty, incoherence, and dissonance give rise to negative affect (Phaf & Rotteveel, 2012), we suggest that actions that modify a situation in a way that increases congruency are facilitated as compared to actions that modify a situation in a way that increases incongruency.

In the present study, we demonstrate that actions are, in fact, facilitated when they modify a conflict-laden situation in such a way that it becomes conflict-free as compared to actions that modify a conflict-free situation in such a way that it becomes conflict-laden. At the same time, we identify an important constraint of that modification effect: only when the produced modification is perfectly predictable in terms of stimulus identity, a benefit of conflict-removing actions emerges, presumably because uncertainty invokes negative affect as conflict does. We will start with the role of conflict first, but return to the role of uncertainty after the presentation of the first experiment.

Experiment 1

We used a standard conflict-inducing task, the Stroop task. Participant's task was to classify the color of a word on the screen and to ignore its content. However, as an effect of their responses, participants modified the situation (the stimulus) foreseeably in either one of two ways. In the *congruent modification condition*, responses changed incongruent distractor words to the respective congruent distractor word, while already congruent stimuli remained unchanged. For example, a correct response to the word BLUE printed in red color (thus an incongruent event) modified the word BLUE to the word RED in red color (rendering it to a congruent stimulus, cf. Fig. 1). Conversely, in the *incongruent modification condition*, responses changed congruent stimuli to incongruent stimuli (e.g., the word RED in red color changed to the word BLUE in red color), while incongruent stimuli remained unchanged. Consequently, in the

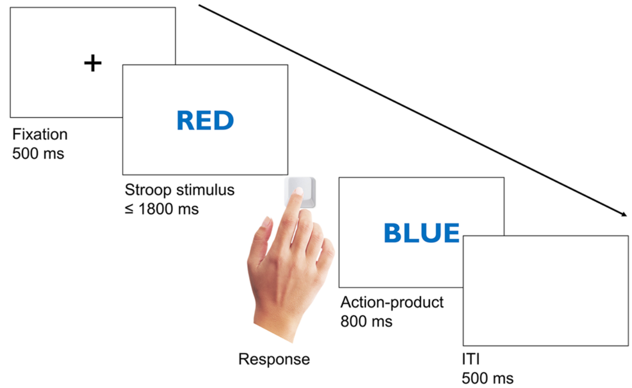

Fig. 1 Exemplary trial sequence of an initially incongruent stimulus in the congruent modification condition in Experiment 1. The word RED printed in blue changes towards the word BLUE printed in blue after the delivery of a correct response

incongruent modification condition, actions always produced (or retained) an incongruent Stroop stimuli, whereas, in the *congruent modification condition*, actions always produced (or retained) congruent Stroop stimuli. The mere observation of incongruent Stroop stimuli is known to produce negative affect, compared to the mere observation of congruent stimuli (Dreisbach & Fischer, 2012). If people repel from actions that modify the current situations to more negative ones, responses that produce incongruency should be harder to generate than responses that produce congruency. We thus propose that response generation is impeded if responses foreseeably change congruent stimuli to incongruent stimuli (thereby producing aversive stimulation), whereas it is facilitated when responses foreseeably change congruent stimuli to incongruent stimuli (thereby getting rid of aversive stimulation). Consequently, we expected participants to respond slower when they had to produce an incongruent action product compared to when they had to produce a congruent action product, and thus, the reaction times (RTs) in the *incongruent modification condition* should be longer than in the *congruent modification condition*.

Methods

Participants

Due to the unclear effect size that we could expect, we used the number of participants that were available to us for each experiment. In Experiment 1, 40 participants took part for either monetary compensation or course credit. All participants gave written informed consent. One participant of this sample was excluded from statistical analyses due to an extremely high error rate (> 5.5 standard deviations from the mean of all participants). Furthermore, due to a technical error, for two participants only the data for one *modification* condition were recorded. They were also excluded, which left a sample of 37 participants for analysis (age: $M = 29.41$, $SD = 9.12$; 23 females; 32 right-handed).

Apparatus and stimuli

Participants sat in front of a 22″ TFT monitor at a distance of about 90 cm. Their task was to do a standard color-word Stroop task. Whenever one of the words ROT, BLAU, or GELB (RED, BLUE, and YELLOW in German) was printed in either red, blue, or yellow they had to press a corresponding key on a standard German QWERTZ keyboard. Mapping of the response keys D, F, and J to colors was counterbalanced across participants.

Procedure

To get familiar with the Stroop task, participants underwent a training sessions of 12 trials in which the exact stimulus which they reacted to was presented as an action product after their response. Afterwards, they underwent the two modification conditions in separate blocks of 264 trials each. The order of blocks was counterbalanced across participants (19 did the incongruent modification first; 18 did the congruent modification first).

Each trial started with a black fixation cross, centrally presented on white background for 500 ms. Then, the Stroop stimulus appeared centrally on white background. The stimulus stayed until participants responded or 1800 ms went by. If participants failed to respond during that deadline or pressed the wrong key, they got an error message ("Zu langsam!", which means too slow; or "Falsche Taste!", which means wrong key).

After a correct response, the action product appeared in the target color for 800 ms. Congruent stimuli in the congruent modification lead to the same word being presented as an action product, while, for incongruent stimuli, the distractor word changed towards the action-product word corresponding to the target color. In the incongruent modification, the word stayed the same for incongruent stimuli, whereas, for congruent stimuli, the distractor word changed from the one describing the target color to one of the two incongruent alternatives. No additional response to these action products was required from participants. After the presentation of the action product, an inter-trial interval (ITI) of 500 ms appeared as a blank screen before the next trial started. In both modification conditions, half of the stimuli were congruent, whereas the other half was incongruent and they appeared in a random order. Between the two blocks, there was a self-paced break.

Results

Data treatment

As it takes some time to learn that responses consistently produce certain action products, we excluded the first 64 trials of each block as learning trials. This planned exclusion left 100 trials for each of the four cells for statistical analyses. From those, we excluded all erroneous trials for RT analyses (4.0%). We also excluded outliers, i.e., RTs that deviated more than 2.5 *SD*s from their respective cell mean (2.7%). Data were submitted to a repeated-measures analysis of variance (ANOVA) with the factors stimulus congruency (congruent vs. incongruent) and modification (congruent modification vs. incongruent modification).

Reaction times

Participants responded faster to congruent stimuli ($M = 523$ ms, $SD = 68$ ms) than to incongruent stimuli ($M = 579$ ms, $SD = 92$ ms, see Fig. 2), $F(1, 36) = 73.45$, $p < .001$, $\eta_p^2 = .67$. Most importantly, the predicted main effect of *modification* was significant, $F(1, 36) = 4.80$, $p = .035$, $\eta_p^2 = .12$. RTs were slower in the *incongruent modification* block ($M = 558$ ms, $SD = 88$ ms) than in the *congruent modification* block ($M = 543$ ms, $SD = 73$ ms). The interaction between *stimulus congruency* and *modification* was not significant, $F(1, 36) = 2.63$, $p = .113$, $\eta_p^2 = .07$.

Errors

Error percentage was lower for congruent stimuli ($M = 3.23\%$, $SD = 3.33\%$), than for incongruent stimuli ($M = 4.69\%$, $SD = 4.28\%$), $F(1, 36) = 14.59$, $p = .001$, $\eta_p^2 = .28$. Neither the main effect of *modification* nor its

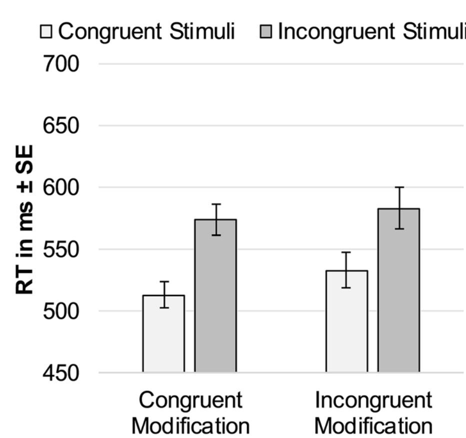

Fig. 2 Mean RTs of Experiment 1, separated by stimulus congruency and modification block. Error bars represent standard error of the means (SE)

interaction with *stimulus congruency* reached significance, $Fs < 1$.

Discussion

Confirming our predictions, Experiment 1 demonstrated that people generate actions more quickly when these actions change an incongruent (possibly aversive) situation towards a congruent (possibly less aversive) situation while leaving congruent situations untouched, as compared to changing congruent-to-incongruent situations while leaving incongruent situations untouched. The error data confirm that the modification effect in RTs was not due to a speed–accuracy trade-off. Moreover, the observation that participants maintained the same level of accuracy in both modification conditions suggests that the difference between modification conditions was not an unspecific strategic effect such as responding more cautiously when incongruent events were produced. Such a strategy should result in an increase of RTs but a reduction of error rates. Moreover, the results cannot be explained by a mere matching of the congruency of the stimulus people respond to and the congruency of the resulting action product. This would have predicted that incongruent stimuli that stay incongruent should be faster than incongruent stimuli that change towards congruency, which is not the case.

Given that the congruency effect in RTs was of the same size in both modification conditions, the benefit from modifying a conflict situation to a congruent one does not differ from the cost of changing a congruent situation into a conflicting one. The relative facilitation of incongruent Stroop trials in the congruent modification condition (second bar from the left in Fig. 2) and the relative slowdown of congruent Stroop trials in the incongruent modification condition (3rd bar in Fig. 2) added up to produce the main effect of modification condition.

Altogether, Experiment 1 supports the assumption that affects regulation processes like situation modification influence responding in conflict tasks. After a closer look at our paradigm, we came up with a possible limitation to the idea that mere change in congruency produces the modification effect. To foreshadow the remainder of the manuscript, this limitation turned out to be important as well as theoretically interesting, and thus, the remaining experiments aimed at scrutinizing this constraint.

In the incongruent modification condition, each congruent stimulus could change into two different incongruent action products (e.g., the word BLUE printed in blue could change into either YELLOW or RED printed in blue). In contrast, in the congruent modification condition, the resulting congruent action product was always perfectly predictable for initially congruent and incongruent stimuli (e.g., to change the word RED in blue to congruency, it had to turn into BLUE printed in blue). Consequently, the incongruent modification invoked uncertainty about outcome identity, whereas the congruent modification did not.

This limitation is theoretically interesting as organisms tend to reduce uncertainty (Friston, 2010), presumably because uncertainty comes with negative affect as conflict does. Chetverikov & Kristjánsson (2016) propose that prediction accuracy prompts the emergence of affect from perception with less expected stimuli causing more negative affect than stimuli whose appearance matches our predictions more closely. Moreover, further evidence for a connection between predictability and affect comes from studies showing that participants prefer visual displays that are predictive of target position in a visual search task to displays that are not (Ogawa & Watanabe, 2011). Even meaningless shapes that only predict an association with another meaningless shape are preferred to ones that do not, suggesting an affective tagging of predictive stimuli (Trapp, Shenhav, Bitzer, & Bar, 2015). Follow-up studies specified that people like stimuli that are predictive of upcoming stimuli the most, compared to predictable stimuli and random stimuli (Braem & Trapp, 2017). Such uncertainty due to prediction errors could be highly related to those produced by a conflict monitoring system and may even stem from the same mechanism (Proulx, Inzlicht, & Harmon-Jones, 2012). What conflict, dissonance and uncertainty supposedly have in common is the production of 'aversive arousal' and efforts to reduce it. Indeed, dissonance produced by an unexpected word at the end of a sentence produced negative affect just like conflict in a recent study (Levy, Harmon-Jones, & Harmon-Jones, 2017). One might thus argue that cognitive conflict is just a specific type of cognitive inconsistency causing negative affect, whereas unpredictability is another one.

This means that the results of Experiment 1 could either be a consequence of incongruency or uncertainty about the identity of the action products. If uncertainty plays a role, it could either be fully responsible for the results, or uncertainty and conflict might add up to produce the modification effect which we found. To pinpoint the role of uncertainty, we ran two experiments: one in which uncertainty was eliminated (Experiment 2) and one in which it was introduced in all conditions (Experiment 3). Finally, we manipulated the congruency of the action products and their predictability orthogonally in Experiment 4.

Experiment 2

Experiment 2 controlled for modification predictability by aligning the number of possible action products in both modification conditions. If the modification effects of Experiment 1 were solely driven by incongruency of the action products, participants should again be slower when they had to produce an incongruent situation compared to when they had to produce a congruent situation, and thus, the RTs in the congruent modification condition should be shorter than in the incongruent modification condition. Whereas, when action-product prediction uncertainty is a necessary condition for the modification effect, no difference between the modification conditions should occur.

Methods

Experiment 2 was mostly equivalent to Experiment 1 except that we reduced the number of possible action products in the incongruent modification condition to match the congruent modification condition. Specifically, for congruent stimuli, the word now always changed into one particular incongruent word, instead of either one of the two words as in Experiment 1. Which action-product word was associated with a certain stimulus was counterbalanced across participants. For example, whereas, in Experiment 1, the stimulus RED printed in red could either produce the action-product BLUE printed in red, or the action-product YELLOW printed in red, it could now only produce the action-product BLUE printed in red. This means that, for each participant, the exact identity of action products was, in principle, predictable in all cells. Thirty-three participants took part (age: $M = 27.45$, $SD = 7.66$; 25 females; 30 right-handed) of which 17 started with the congruent modification block and 16 started with the incongruent modification block.

Results

Data treatment

We used the same exclusion criteria as in Experiment 1. The first 64 trials of each block were excluded as learning trials. Excluded error trials amounted to 4.0% of all trials and outliers amounted to 2.7% of the remaining trials. Again, data were submitted to a repeated-measure ANOVA with the factors stimulus congruency (congruent vs. incongruent) and modification (congruent modification vs. incongruent modification).

Reaction times

RTs for congruent stimuli ($M = 533$ ms, $SD = 72$ ms) were lower than for incongruent stimuli ($M = 595$ ms, $SD = 92$ ms; $F(1, 32) = 81.71$, $p < .001$, $\eta_p^2 = .71$). The main effect of modification block was not significant, $F(1, 32) = 1.75$, $p = .195$, $\eta_p^2 = .05$. Contrary to Experiment 1, a significant interaction of stimulus congruency and modification block emerged, $F(1, 32) = 4.84$, $p = .035$, $\eta_p^2 = .13$, (see Fig. 3). This interaction was caused by a larger congruency effect in the congruent modification block, ($\Delta = 72$ ms, $SD = 55$ ms) than in the incongruent modification block ($\Delta = 54$ ms, $SD = 37$ ms).

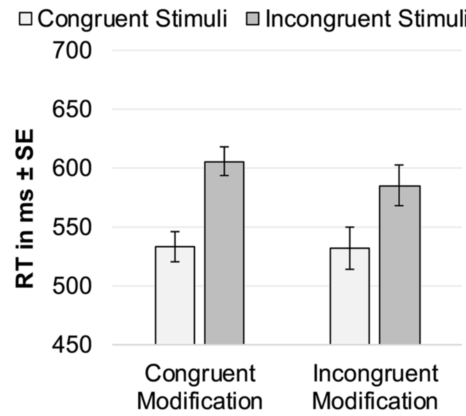

Fig. 3 Mean RTs of Experiment 2 separated by stimulus congruency and modification block. Error bars represent standard error of the mean (SE)

Errors

There was a significant main effect of stimulus congruency, $F(1, 32) = 8.23$, $p = .007$, $\eta_p^2 = .20$. Participants made fewer errors for congruent stimuli ($M = 3.14\%$, $SD = 2.91\%$) than for incongruent stimuli ($M = 4.64\%$, $SD = 4.13\%$). Neither the main effect of modification block, $F < 1$, nor the interaction, $F(1, 32) = 2.90$, $p = .098$, $\eta_p^2 = .08$, reached significance.

Discussion

We did not find an effect of modification when we excluded uncertainty in the incongruent modification block, neither in RTs nor error rates. Thus, the mere incongruency of an upcoming situation does not seem to suffice to produce the modification effect as observed in Experiment 1. The results of the current experiment suggest uncertainty as an important determinant in situation modification. Contrary to Experiment 1, we found a diminished Stroop effect in the incongruent modification condition. We are reluctant to base strong inferences on this effect, since it did not replicate in the other experiments of this study. However, the overall high proportion of incongruent events in the incongruent modification condition (when looking at the incongruent stimuli and products together) might have resulted in an increased recruitment of proactive control in this experiment. Clearly, this speculation would need further support, which was beyond the scope of the present study.

Experiment 3

In Experiment 3, we did not eliminate effect uncertainty as in Experiment 2, but introduced effect uncertainty in all conditions, to see whether the general presence of uncertainty might foster an impact of congruency modification. The main difference was that, in every trial, responses changed not only the distractor word, but also the target color. People could anticipate neither the font color, nor the distractor word of the action product, only whether it would be congruent or incongruent. This means that more features of the situation changed than in the other experiments.

If uncertainty over action-product identity is necessary to bring out the preference of congruent over incongruent modifications, participants should be slower when producing an incongruent action product compared to a congruent action product. Thus, RTs in the congruent modification condition should be shorter than in the incongruent modification condition. If unpredictability and incongruency of modifications can influence behavior only in combination, compared to congruent and predictable modifications, then we expect no difference.

Methods

All action products consisted of a different font color and a different color word than the one participant just responded to. Furthermore, the distractor word of the stimulus never became the font color of the action product. This was accomplished by adding a fourth color (green), so, unlike in the previous experiments, the task was a four color-word Stroop task. For example, in the congruent modification condition, the incongruent stimulus word RED printed in blue would lead to either the action product of the word YELLOW printed in yellow or the word GREEN printed in green. Whenever a word was printed in yellow, participants had to press the D key, for red the F key, for blue the J key, and for green the K key.

Due to balancing reasons, each block now consisted of 240 trials. Twenty-six participants took part (age: $M = 24.65$, $SD = 3.58$; 18 females; 25 right-handed) of which 13 started with the congruent modification block and 13 started with the incongruent modification block.

Results

Data treatment

We excluded the first 64 trials as learning trials. For RT analysis, we excluded error trials (7.0%) and outliers (2.8%). We calculated a repeated-measures ANOVA with the factors stimulus congruency (congruent vs. incongruent) and modification block (congruent modification vs. incongruent modification).

Reaction times

RTs for congruent stimuli ($M = 633$ ms, $SD = 111$ ms) were lower than for incongruent stimuli ($M = 743$ ms, $SD = 152$ ms; see Fig. 4), $F(1, 25) = 92.77$, $p < .001$, $\eta_p^2 = .78$. There was neither a main effect of *modification block*, $F < 1$, nor an interaction, $F(1, 25) = 1.68$, $p = .207$, $\eta_p^2 = .06$.

Errors

A similar pattern emerged for the errors. Only the main effect of *stimulus congruency* reached significance, $F(1, 25) = 9.95$, $p = .004$, $\eta_p^2 = .29$, with fewer errors for congruent ($M = 5.65\%$, $SD = 4.12\%$) than for incongruent stimuli ($M = 8.43\%$, $SD = 6.70\%$). There was neither a main effect of *modification* block, $F(1, 25) = 1.33$, $p = .261$, $\eta_p^2 = .05$, nor an interaction, $F < 1$.

Discussion

We did not observe a modification effect, when both modification conditions were equally uncertain with regard to the specific effect which a correct response produced. RTs and error rates were generally much higher in the current experiment than in the previous ones, which most likely was due to the use of a 4-, instead of 3-color-word Stroop task.

To conclude, when response-triggered stimulus modifications are equally certain (Experiment 2) or uncertain (Experiment 3), there seems to be no benefit of modifying stimuli to congruent over incongruent events. This suggests that action production benefits occur only when these actions

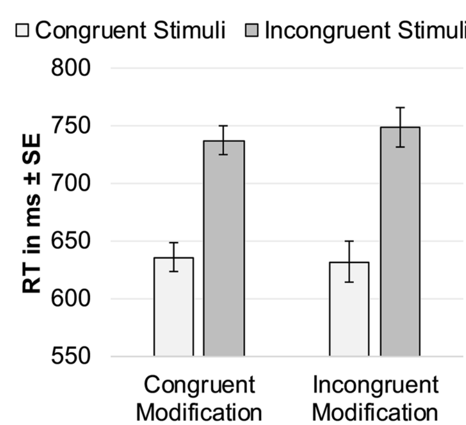

Fig. 4 Mean RTs of Experiment 3 separated by stimulus congruency and modification block. Error bars represent standard error of the mean (SE)

produce events that are both, congruent and predictable. Of course, it might also be the case that the modification effect demonstrated in Experiment 1 was just a spurious observation. Therefore, we aimed to replicate the congruency modification benefit and test directly its dependence on prediction certainty in Experiment 4.

Experiment 4

Experiment 4 manipulated both congruency and predictability of the identity of response-triggered stimulation orthogonally. Assuming that action production benefits emerge only when actions produce events that are both, congruent and predictable with respect to identity, we expected to find facilitated performance only in a condition that met both criteria, as compared to all other conditions that lacked at least one of these criteria.

Methods

As we had more blocks, we reduced the trials in each block and recruited 60 participants for this experiment (age: $M = 27.01$, $SD = 7.60$; 39 females; 56 right-handed). The general trial procedure was the same as in the previous experiments. We used a Stroop task with the colors red, yellow, and blue. We now had four blocks instead of two. In two of the blocks, the specific action product was always predictable; in the other two blocks, it was always unpredictable. In two of the blocks, a response lead to congruent action products, in the other two to incongruent action products. The congruent-predictable block was exactly as the congruent modification block in Experiment 1 and 2. In the incongruent-predictable block, each particular stimulus color had exactly one incongruent color-word action product associated with it (e.g., all red stimuli always turned into BLUE in yellow), so that the identity of the action product was clear from stimulus color, and thus response. Contrary to the incongruent-predictable modification condition in Experiment 2, stimulus color always changed in Experiment 4 (e.g., RED in red turned into BLUE in yellow as well as BLUE in red into BLUE in yellow), whereas participants merely changed the distractor word in Experiment 2 (e.g., RED in red turned into BLUE in red and BLUE in red remained BLUE in red). In the congruent-unpredictable block, every stimulus could be followed by each of the three possible congruent action products. In the incongruent-unpredictable block, every stimulus was associated with three incongruent action products.

To make the experiment bearable for the participants, we reduced the number of trials per block to 180. Another adjustment aimed at directing participants' attention towards the events they produced. These were nominally task-irrelevant and could be ignored in principle, so that any variation of the type of produced events may not be registered at all (though at least the data of Experiment 1 speak against this possibility). Therefore, we included a contingency awareness check after each block. Participants were shown one congruent and one incongruent stimulus, and were asked which of the overall nine possible action products followed those stimuli in the previous block. The order in which a participant completed the four conditions was determined by permutation selection.

Results

Data treatment

The exclusion criteria were equal to those of the previous studies. For the RT analysis, we excluded errors (7.0%) and outliers (2.7%). The data were submitted to a 2×2×2 ANOVA with the factors stimulus congruency (congruent vs. incongruent), modification congruency (congruent vs. incongruent), and modification predictability (predictable vs. unpredictable). We expected an interaction of modification congruency and modification predictability. These two-way interactions were scrutinized in planned two-tailed paired-samples t tests. The standardized mean difference effect size for within-subjects designs, Cohen's d_z, was calculated for pairwise comparisons (Lakens, 2013).

Reaction times

The main effect of stimulus congruency was significant (see Fig. 5), $F(1, 59) = 210.44$, $p < .001$, $\eta_p^2 = .78$. RTs for congruent stimuli ($M = 596$ ms, $SD = 99$ ms) were lower than for incongruent stimuli ($M = 673$ ms, $SD = 122$ ms). There was also a significant main effect of modification congruency, $F(1, 59) = 28.22$, $p < .001$, $\eta_p^2 = .32$. Participants responded faster when they created a congruent action product ($M = 610$ ms, $SD = 108$ ms) than when they created an incongruent action product ($M = 657$ ms, $SD = 120$ ms). The main effect of modification predictability was also significant, $F(1, 59) = 8.63$, $p = .005$, $\eta_p^2 = .13$. When action products were predictable, participants responded faster ($M = 618$ ms, $SD = 112$ ms) than when they were unpredictable ($M = 649$ ms, $SD = 120$ ms).

As predicted, the interaction of modification congruency and modification predictability was significant, $F(1, 59) = 25.87$, $p < .001$, $\eta_p^2 = .31$. There was only a significant difference between producing the congruent ($M = 576$, $SD = 109$ ms) and the incongruent action products ($M = 662$ ms, $SD = 134$ ms) when their appearance was predictable, $t(59) = 6.77$, $p < .001$, $d_z = .87$. When it was unpredictable, there was no difference between the congruent ($M = 646$ ms, $SD = 125$ ms) and the incongruent

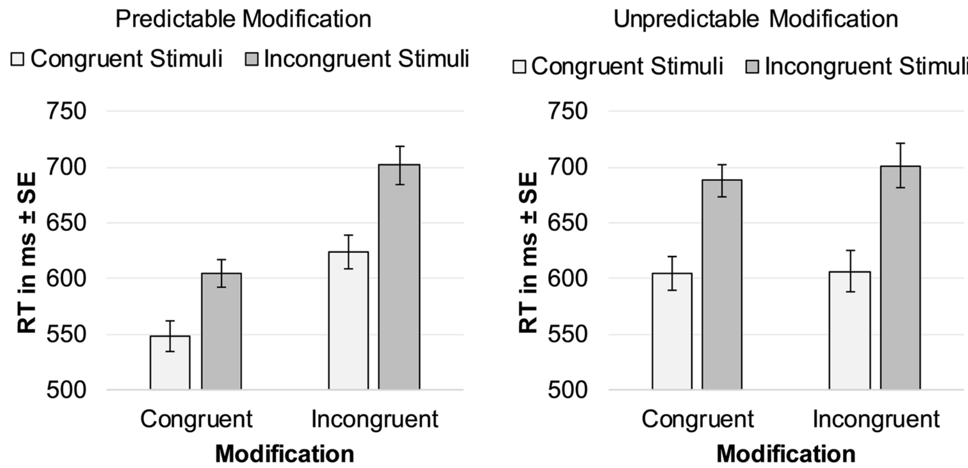

Fig. 5 Mean RTs of Experiment 4 separated by modification predictability and plotted as a function of stimulus congruency and modification congruency. Error bars represent standard error of the mean (SE)

($M = 652$ ms, $SD = 129$ ms) modification conditions, $t(59) = .62$, $p = .535$, $d_z = .08$.

The interaction of stimulus congruency and modification congruency was also significant, $F(1, 59) = 5.84$, $p = .019$, $\eta_p^2 = .09$. The congruency effect was smaller in the congruent modification blocks ($\Delta = 69$ ms, $SD = 38$ ms), than in the incongruent modification blocks ($\Delta = 86$ ms, $SD = 59$ ms). Furthermore, the interaction of stimulus congruency and modification predictability was significant, $F(1, 59) = 10.81$, $p = .002$, $\eta_p^2 = .16$. The congruency effect was smaller in the predictable modification blocks ($\Delta = 66$ ms, $SD = 44$ ms), than in the unpredictable modification blocks ($\Delta = 88$ ms, $SD = 53$ ms). The three-way interaction of stimulus congruency, modification congruency, and modification predictability was not significant, $F < 1$.

In addition, we calculated an exploratory analysis that sought to examine whether responding to conflict stimuli in the predictable, congruent modification condition ($M = 604$, $SD = 116$) differed from RTs to congruent stimuli in any of the other conditions (predictable-incongruent modification: $M = 624$, $SD = 122$; unpredictable-congruent modification: $M = 605$, $SD = 115$; unpredictable-incongruent modification: $M = 607$, $SD = 111$). There was no significant difference (all $ps > 0.080$), which means that even though responding to conflict was not faster than responding to congruent stimuli, participants were able to respond as quickly to conflict that predictably changed into congruent action products, than to congruent stimuli that were either modified unpredictably, incongruently, or both.

Errors

For the errors, there was a significant main effect of stimulus congruency , $F(1, 59) = 50.04$, $p < .001$, $\eta_p^2 = .46$, with fewer errors for congruent ($M = 5.33\%$, $SD = 3.74\%$) than for incongruent stimuli ($M = 8.64\%$, $SD = 5.21\%$). The main effect of modification congruency was also significant, $F(1, 59) = 25.38$, $p < .001$, $\eta_p^2 = .30$. Participants made fewer errors when they produced a congruent action product ($M = 6.18\%$, $SD = 3.88\%$) than when they produced an incongruent one ($M = 7.80\%$, $SD = 4.75\%$).

There was no significant main effect of modification predictability, $F < 1$. The hypothesized interaction of modification congruency and modification predictability was significant, $F(1, 59) = 13.33$, $p = .001$, $\eta_p^2 = .18$. Mirroring the RT results, the difference between congruent modification ($M = 5.42\%$, $SD = 4.30\%$) and incongruent modification ($M = 8.83\%$, $SD = 5.40\%$) was only significant in the predictable modification condition, $t(59) = 5.68$, $p < .001$, $d_z = .73$. Producing congruent ($M = 6.94\%$, $SD = 4.41\%$) and incongruent action products ($M = 7.26\%$, $SD = 5.00\%$) did not differ in the unpredictable modification condition, $t(59) = .72$, $p = .475$, $d_z = .09$. The interaction of stimulus congruency and modification congruency was also significant, $F(1, 59) = 8.99$, $p = .004$, $\eta_p^2 = .13$. The congruency effect was smaller in the congruent modification blocks ($\Delta = 2.35\%$, $SD = 3.84\%$), than in the incongruent modification blocks ($\Delta = 4.28\%$, $SD = 4.89\%$). Neither the interaction of stimulus congruency and modification predictability nor the three-way interaction was significant, $Fs < 1$.

Discussion

As predicted, we found an interactive influence of the congruency of a to-be-produced modification and the (un)predictability of that modification on response latencies. In addition, this interaction also manifested in the error rates. The strength of the modification manipulation is nicely illustrated by comparing the second and third bars from the left in Fig. 5: RTs to incongruent Stroop stimuli, which foreseeably changed to a specific congruent action product, were slightly lower than to congruent Stroop stimuli, which foreseeably changed to a specific incongruent action product, although this difference was only marginally significant. This shows that the interfering influence of unpredictable or incongruent action products was of at least a similar size as the Stroop-conflict interference.

Even though action products always appeared after the response and had no relevance for the response, the anticipation of these changes had strong ramifications. There was no difference between the incongruent-predictable modification (in which participants could always predict the identity of the upcoming incongruent action product upon stimulus presentation) and both of the unpredictable conditions, which shows that better prediction alone does not lead to facilitation of responding. Furthermore, we observed a difference between the incongruent-predictable modification and the congruent-predictable modification.

The Stroop effect itself (i.e., the performance difference between initially congruent and incongruent stimuli) was significantly reduced when the action outcome was congruent compared to when it was incongruent and when the action outcome was predictable compared to when it was unpredictable. This suggests that unpredictability of upcoming action products has a detrimental impact on cognitive control. The influence of action-product congruency is different to Experiment 2 where the Stroop effect was larger in the incongruency production condition, so we are hesitant to draw strong conclusions from it. Still, the opportunity to modify a situation seems to have the power to modulate the conflict that comes with initially identical stimulation. This, we believe, is an interesting observation that underlines the general assumption of a close link between conflict and emotion regulation and certainly warrants further investigation.

Interestingly, we found no difference between predictable congruent vs. incongruent modification blocks in Experiment 2, whereas we did in Experiment 4. One difference between the experiments is that in Experiment 4, each stimulus color (and thus response) produced an incongruent color-word that did not match the color of that response. For example, RED in red turned into BLUE in yellow, but so did also BLUE in red. Thus, there was always a font color change. In Experiment 2, the identity of the produced incongruent event was also predictable, but the stimulus color was always retained (e.g., RED in red turned into BLUE in red and BLUE in red remained BLUE in red). Thus, predictably retaining stimulus color might be a particularly strong factor for reducing uncertainty and speeding up response production. This factor varied between predictable congruent vs. incongruent modification conditions in Experiment 4 but not in Experiment 2.

General discussion

Humans tend to change a negative situation to one that is more positive, an emotion-regulating behavior known as situation modification (Gross, 1988). Assuming that cognitive conflict is aversive, we conjectured that humans would also be inclined to modify a conflict-laden stimulation to one that is conflict-free rather than the other way round. In line with this assumption, we found that responses in a classical interference situation, the Stroop task, were generated more quickly when they consistently produced congruent rather than incongruent stimulation. However, this applies only when the produced stimulation was fully predictable with respect to action-product congruency and identity.

Conflict and certainty

Why did action production benefit only when actions consequences were both predictably congruent and of a specific identity? We see two explanations for this. First, humans not only prefer situations with low rather than high levels of interference (e.g., Dignath & Eder, 2015), but also situations that are predictable to those that are unpredictable (Ogawa & Watanabe, 2011).

Interference is only one instance of a range of cognitive inconsistencies that could evoke ‘aversive arousal’ (Proulx, Inzlicht, & Harmon-Jones, 2012). People also aim at reducing uncertainty (Friston, 2010), because certainty is judged more positive than uncertainty, so as conflict-free stimulation is judged more positive than conflict-laden stimulation (Chetverikov & Kristjánsson, 2016). Perhaps, only anticipated conflict-free and perfectly certain stimulation comes with sufficient affective improvement to bias behavior. Second, it might be that only specific stimulus identities are bound to and predicted by certain motor actions, which then inevitably also contain a certain congruency level. For example, participants may not have learned that a left keypress produced congruent stimuli, when there is more than one congruent stimulus. Rather, what they have learned might be that a left response produced the word BLUE in blue, and only then does it become clear that this is a congruent event. In other words, the acquisition of links between specific actions and specific action effects might come first, and only then might the implied (in)congruency of that specific effect be acquired and influence response selection. A couple of observations from research on action-effect learning suggest that the latter interpretation is not very likely. Most notably, actions can be bound to specific effect categories such as furniture or animals (Hommel, Alonso, & Fuentes, 2003) or positive or negative objects (Eder, Rothermund, De Houwer, & Hommel, 2015), irrespective of specific effect identities.

A third possibility is that the anticipation of a word that matches the meaning of the correct response facilitated responding. In those conditions in which participants produced an action product that was both congruent and predictable, the word presented after the response matched the correct answer. For example, the word RED in blue color, which required a “blue” response, was replaced by the word BLUE in blue color, or the word BLUE in blue color, which also required a “blue” response, was repeated. Maybe, anticipated positive feedback of producing a distractor corresponding to the current action is responsible for the facilitation of such actions.

While we cannot rule out this account by means of the present data, it seems unlikely in view of previous research. Specifically, Hommel (2004, Exp. 3) observed that response effects consisting of color words printed in a neutral color did not impact responding to color stimuli. Thus, it seems unlikely that distractor words as action effects in themselves bias responding. While this interpretation certainly deserves further investigation, we conclude, for the time being, that the action effects have to be congruent in color and word to generate a facilitating effect. One possibility to rule out this alternative explanation is to conduct a study in which predictable, congruent action products that do not match the correct answer are compared to unpredictable and incongruent action products that do not match the correct answer, as well. For example, every red stimulus turns into the word BLUE printed in blue in the predictable-congruent modification condition, whereas, in the unpredictable-incongruent condition, every red stimulus turns into either GREEN printed in yellow or BLUE printed in yellow. If there is still a difference between those conditions, this would suggest that upcoming congruency and predictability are, indeed, the important factor in such modification effects.

What does this tell us about affect and conflict?

Derived from the extended process model of emotion regulation, we hypothesized that people would be inclined towards modifying situations towards the better rather than towards the worse (e.g., Beckers, De Houwer, & Eelen, 2002). The important point here is that the produced action products contained neither positive nor negative valence per se. It might be that perfectly predictable congruent color words prompt more positive affect than perfectly predictable-incongruent or unpredictable-congruent color words, as suggested by the previous evidence (Dreisbach & Fischer, 2012). However, this remains to be tested for the present modification paradigm. Preliminary data of our lab suggest that incongruent imperative stimuli are judged as being more negative than congruent stimuli. Yet, the modification of these stimuli does not seem to come with immediate changes of affect. This suggests that the interplay between conflict management and affect regulation is likely more complex than initially assumed. Still, the idea that strategies to cope with negative affect are also involved to cope with cognitive conflict is an intriguing one, and a promising way to examine further. For example, another emotion regulation strategy is to inhibit the expression of emotion. Likewise, there is now evidence that the response-activating impact of conflict-laden distractors (i.e., the expression of conflict) can be modulated strategically (Jost, Wendt, Luna-Rodriguez, Löw, & Jacobsen, 2017).

Whereas Exp. 2 showed smaller Stroop effects in the incongruent than the congruent modification condition with overall predictable action products, Exp. 4 showed reduced Stroop effects for congruent compared to incongruent modifications and for predictable compared to unpredictable modifications. Apparently, the availability of one conflict management strategy (situation modification) can interact with the use of other possible strategies to cope with conflict/negative affect, such as deployment of attention. This observation points to a very important question for future research. How does the availability of one regulation strategy affect the use of other equally feasible strategies? Would participants, for example, still focus more on relevant information if conflict was announced in advance (Wühr & Kunde, 2008), even though they could predictably modify the conflicting situation as they could here? Obviously, question like these wait for a closer examination.

Conclusion

In the present study, we demonstrated for the first time that motor responses in a widely used interference task are facilitated when they foreseeably produce a specified conflict-free situation. Future studies should address whether feedback processes play a role for the observed effect or whether it is exclusively a consequence of similar regulation processes for cognitive conflict and negative affect. We assume that taking this similarity serious will reveal further commonalities between affective and cognitive processes.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Research involving human and animal participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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