Affective regulation of cognitive conflict

Inaugural-Dissertation

zur Erlangung der Doktorwürde der

Fakultät für Humanwissenschaften

der

Julius-Maximilians-Universität Würzburg

Vorgelegt von

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Würzburg

2021

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Tag des Kolloquiums: 11.12.2020

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Sieben Experimente der vorliegenden Dissertation wurden bereits in akademischen Fachzeitschriften veröffentlich (Schmidts, Foerster, & Kunde, 2019, 2020). Da alle Methoden, Ergebnisse und Diskussionen dieser Studien unverändert für die Dissertation übernommen wurden, sind einige Textstellen aus diesen Publikationen vollständig beibehalten worden. Dies ist im Einklang mit dem Urheberrecht von Springer Nature (*Psychological Research)* und Taylor & Francis (*Cognition and Emotion).*

Anteil aller beteiligten Autorinnen und Autoren:

Schmidts, Constantin; Foerster, Anna; Kunde, Wilfried (2020): Situation selection and cognitive conflict: explicit knowledge is necessary for conflict avoidance. *Cognition & emotion*, 1–11. DOI: 10.1080/02699931.2020.1736006.

Studienidee, Studiendesign und statistische Analyse von Constantin Schmidts. Anna Foerster und Wilfried Kunde gaben Rückmeldung zu dem geschriebenen Manuskript.

Schmidts, Constantin; Foerster, Anna; Kunde, Wilfried (2019): Conflict modification: predictable production of congruent situations facilitates responding in a stroop task. *Psychological research* 83 (8), 1722–1732. DOI: 10.1007/s00426-018-1021-8.

Studienidee, Studiendesign und statistische Analyse von Constantin Schmidts. Anna Foerster und Wilfried Kunde gaben Rückmeldung zu dem geschriebenen Manuskript.

1 Zusammenfassung

Kognitive Kontrolle beschreibt Prozesse die nötig sind um zielgerichtetes Handeln im Angesicht von internen oder externen Widerständen zu ermöglichen. Wenn wir aus eigenen Stücken oder inspiriert durch unsere Umwelt Handlungen vorbereiten die unseren aktuellen Zielen entgegen stehen, kommt es zu Konflikten. Solche Konflikte können sich auf nachfolgendes Erleben und Verhalten auswirken. Aversive Konsequenzen von Konflikt könnten in einem Konfliktüberwachungsmodul registriert werden, welches anschließend Aufmerksamkeitsänderungen und Handlungstendenzen zur Reduzierung dieses negativen Affektes in Gang setzt. Wenn das der Fall wäre, könnten die vielfach beobachteten Verhaltensanpassungen an kognitiven Konflikt ein Ausdruck von Emotionsregulation sein. Ein theoretischer Eckpfeiler der gegenwärtigen Forschung zur Emotionsregulation ist das Prozessmodell der Emotionsregulation, das aus den Regulationsstrategien Situationsauswahl, Situationsmodifikation, Aufmerksamkeitslenkung, kognitiven Veränderungen und Reaktionsmodulation besteht. Unter der Annahme, dass Konfliktanpassung und Affektregulation auf gemeinsamen Mechanismen fußen, habe ich aus dem Prozessmodell der Emotionsregulation Vorhersagen zur kognitiven Kontrolle abgeleitet und diese in elf Experimenten getestet ($N = 509$). Die Versuchsteilnehmer zeigten Situationsauswahl in Bezug auf Konflikte, allerdings nur dann, wenn sie ausdrücklich auf Handlungs- und Ergebniskontingenzen hingewiesen wurden (Experimente 1 bis 3). Ich fand Anzeichen für einen Mechanismus, der der Situationsmodifikation ähnelt, aber keine Hinweise auf eine Beteiligung von Affekt (Experimente 4 bis 10). Eine Änderung der Konfliktbewertung hatte keinen Einfluss auf das Ausmaß der Konfliktadaptation (Experiment 11). Insgesamt gab es Hinweise auf eine explizite Aversivität kognitiver Konflikte, jedoch weniger auf implizite Aversivität, was darauf hindeutet, dass Konflikte vor allem dann Affektregulationsprozesse auslösen, wenn Menschen explizit Affektregulationsziele vor Augen haben.

2 Summary

Cognitive control is what makes goal-directed actions possible. Whenever the environment or our impulses strongly suggests a response that is incompatible with our goals, conflict arises. Such conflicts are believed to cause negative affect. Aversive consequences of conflict may be registered in a conflict monitoring module, which subsequently initiates attentional changes and action tendencies to reduce negative affect. This association suggests that behavioral adaptation might be a reflection of emotion regulation. The theoretical cornerstone of current research on emotion regulation is the process model of emotion regulation, which postulates the regulation strategies situation selection, situation modification, attentional deployment, cognitive change, and response modulation. Under the assumption that conflict adaptation and affect regulation share common mechanisms, I derived several predictions regarding cognitive control from the process model of emotion regulation and tested them in 11 experiments (N = 509). Participants engaged in situation selection towards conflict, but only when they were explicitly pointed to action-outcome contingencies (Experiments 1 to 3). I found support for a mechanism resembling situation modification, but no evidence for a role of affect (Experiments 4 to 10). Changing the evaluation of conflict had no impact on the extent of conflict adaptation (Experiment 11). Overall, there was evidence for an explicit aversiveness of cognitive conflict, but less evidence for implicit aversiveness, suggesting that conflict may trigger affect regulation processes, particularly when people explicitly have affect regulation goals in mind.

3 Introduction

Imagine you are a smoker who is trying to quit. Whenever you feel the urge to smoke, you chew some gum instead. This strategy works effortlessly as long as you are surrounded by other people chewing gum. However, encountering other smokers outside leads to the behavioral impulse to smoke a cigarette instead. That makes you feel torn, but you successfully fight the urge and subsequently find it easier to keep on chewing gum, when you come across different cues like an advertisement for your favorite cigarette brand. Did the bad feeling from the described goal conflict help you to overcome the temptation? Might the recruitment of cognitive resources even be a response to deal with these negative feelings?

In our daily life, we often encounter attractions that are at odds with our current goals. Nevertheless, we mostly manage to overcome the action tendencies that these stimuli propose and go about our life in a goal-directed manner. The exceptions to this rule have an enormous personal and economic impact (e.g., addiction, or unhealthy eating behavior; American Psychiatric Association, 2013). To overcome conflicts between current task goals and actions facilitated by our environment, we have to engage in cognitive control (Shiffrin & Schneider, 1977). How does cognitive control work? Do affective consequences of conflict play a role in cognitive control of said conflicts? If they do, can we apply existing knowledge on the regulation of affect to the regulation of cognitive control?

The existence of an emotional system that requires taming by a cognitive system goes back to early Greek philosophers (e.g., Plato's *logistikon,* Plato & Loewenthal, 2004). Contemporary theories proposing these two separate systems often describe behavior as a struggle between emotion and cognition (Kahneman, 2011). In this two-system framework, an automatic, inflexible emotional system is contrasted with an effortful, flexible cognitive system. If those systems are in conflict, motivation, and resource capacities determine the winning system that will determine behavior. This duality has not only been proposed for higher-order decision-making behavior but also for lower-level behavior in human and nonhuman animals. For instance, an emotional system separate from a cognitive system has been postulated for the neural underpinnings of the learning processes behind emotions like fear (LeDoux, 2003). Here, the behavior is initially based on automatic response tendencies, which can be later modulated by cognitive processes. All of these conceptions assume a clear division between emotion and cognition. This notion may not be entirely accurate. Bidirectional influences between cognition and emotion may emerge on all stages of either. Behavior is by and large based on a variety of mental processes and brain networks that are not purely cognitive or affective (Pessoa, 2008).

Additionally, cognitive as well as emotional conscious experience may rely on processes and brain substrates, that are so similar that they cannot be meaningfully separated (LeDoux & Brown, 2017). Consequently, the explanation of said mental processes could benefit from drawing on findings and concepts from the research on cognition as well as the research on emotion and bring them together. One way to approach this is to study cognitive conflicts.

Conflict created by incompatible mental representations and its influence on human information processing has been of interest to psychologists for a long time. For example, Festinger (1962) argued that conflicting attitudes, beliefs, or behaviors lead to cognitive dissonance. People try to avoid states of cognitive dissonance and thus change their behavior or their attitudes. These attitudinal changes then successfully diminish the unpleasant state produced by such a conflict (Losch & Cacioppo, 1990). From early on, the degree of processing conflict and uncertainty in the information processing system has been implicated in motivating behavior (Berlyne, 1957).

Whereas some presume that conflicts between higher-order goals may be necessary for the emergence of emotions (Oatley & Johnson-laird, 1987), similar ideas for lower-level cognitive conflicts just recently surfaced. However, precursors can already be found in writings by early psychologists. John Dewey's description of emotion included this passage: *"… if the stimulating and the induced activities need to be coordinated together, if they are* *both means contributing to one and the same end, then the conditions for mere habit are denied, and some struggle, with incidental inhibitory deflection of the immediate activity, sets in.*" (Dewey, 1895, p. 27). This description resembles the resolution of cognitive conflict, in which habits have to be overcome, and the irrelevant response has to be inhibited. If these parallels are taken at face value, the conditions for emotion to arise might even be met in the experience of cognitive conflict.

Cognitive conflict occurs when a more automatic process has a different behavioral endpoint than a more controlled process (Shiffrin & Schneider, 1977). More generally, cognitive conflict refers to the interference of at least two ongoing processes (Botvinick, Braver, Barch, Carter, & Cohen, 2001) which can arise due to an overlap between different features of a stimulus or a response (Kornblum, Hasbroucq, & Osman, 1990). In the common classification tasks used to probe cognitive control in the laboratory, the features can be low-level perceptual features, like color and semantic content in the Stroop task (Stroop, 1935), distinct letters in the Eriksen Flanker task (Eriksen & Eriksen, 1974), or color and spatial location in the Simon task (Simon & Rudell, 1967).

Recent experiments showed that perception of cognitive conflict in a Stroop task could cause negative affect (Dreisbach & Fischer, 2012). Given this association of negative affect and conflict, affect regulation strategies usually used to deal with emotions like disgust, anger, or pleasure (Gross, 1998a), may also play a role in conflict processing. Accordingly, the proposal emerged to view changes in cognitive control as a kind of emotion regulation (Saunders, Milyavskaya, & Inzlicht, 2015). Allocating control might be just one mechanism to regulate affect in conflict situations. A vast literature targets the regulation of emotion, but the most widely accepted theoretical framework is the process model of emotion regulation (Gross, 1998b). According to this model, there are five target points of emotion regulation in the timeline of an emotional event. If agents choose to expose themselves to a particular situation based on its anticipated affective consequences, they engage in *situation selection.* If agents alter a chosen situation to change its affective effect, they engage in *situation modification*. Another strategy is *attentional deployment* towards or away from affect eliciting properties of the environment. *Cognitive change* describes how the subjective interpretation of a situation modifies its emotional impact. Finally, the reaction to an emotional episode is a function of *response modulation.* These emotion regulation strategies differ in their effectiveness, with active distraction and reappraisal of the emotional stimulus as the most effective (Webb, Miles, & Sheeran, 2012).

Initially developed to describe how humans deal with full-blown emotion, an updated version, the so-called extended process model describes the regulation of all affective situations. Regulation occurs whenever a discrepancy between a desired emotional state and the actual emotional state is detected, and actions are taken to reduce this discrepancy (Gross, 2015). I will examine whether people chose to regulate the consequences of the experience of conflict by situation selection processes, situation modification processes, and whether the identification stage can be modulated to increase control adaption.

3.1 Cognitive control

Cognitive control refers to top-down processes that coordinate our actions according to internal goals (Miller & Cohen, 2001). We encounter a vast amount of sensory information and have a variety of behaviors to choose from at any given moment. To optimize behavior in light of all these different options, a set of functions evolved in humans that use internal goals to guide behavior, which is especially required as soon as there are compelling behavioral options present that are in contrast with those goals (J. D. Cohen, 2017). Whereas in early scientific analyses, these phenomena were known as *will* (Ach, 1935; James, 1890), currently, the preferred names are executive functions or cognitive control. Executive functions are commonly divided into three subcomponents: inhibition, working memory, and cognitive flexibility (Diamond, 2013). Inhibitory control helps us to suppress habitual actions or actions that are strongly suggested by external stimuli when those are in conflict with our goals. Working memory describes our ability to hold information in our mind that is no longer perceptually present and perform mental operations on this information (Cowan, 2017). The third core executive function is called cognitive flexibility and contains adaptation in light of changing task demands, e.g., in task switching (Braem & Egner, 2018; Kiesel et al., 2010).

In the current thesis, I focus on inhibitory control and use one prominent task to examine this aspect of cognitive control, the Stroop task (Stroop, 1935). In a classic Stroop task, people see a color word (e.g., red) printed in a specific color, which can be the same (congruent) or a different color (conflict or incongruent). The task is to identify the printed color while ignoring the color word. The habit of automated word reading activates the representation of the color word quickly. If the to be identified color is the same as the color word (congruent trials), responding is facilitated. Whenever word content and word color are different (incongruent trials), the activated representation of an incorrect color interferes with the slower and less automated task of color identification. It has to be overcome in order to classify the color of the word correctly (J. D. Cohen, Dunbar, & McClelland, 1990). As such, cognitive conflict is assessed via performance differences between these congruent and incongruent conditions (i.e., congruency effects). Successful responding to an incongruent Stroop trial demonstrates the ability to select a weaker response over a stronger, but incorrect response, which is the hallmark of controlled information processing. In light of progress concerning the consequence of control and its neural correlates (in the prefrontal cortex, Miller & Cohen, 2001), new questions took priority. One highly debated question was and is how the concept of cognitive control can explain the recruitment, modulation, and disengagement of control without resorting to a *homunculus*, a little person in my head that decides whenever to allocate control (Monsell & Driver, 2000).

To get rid of the *homunculus,* Botvinick et al. (2001) proposed a conflict monitoring module that detects whenever conflict in information processing occurs (i.e., one process is subjected to cross-talk from a process it shares an overlapping pathway with; Berlyne, 1957). This conflict monitoring module subsequently sends a signal to upregulate cognitive control if the current allocation of control is inadequate to address the prevailing task requirements.

In this model, there is no more need for a central executive. Botvinick et al. (2001) locate this conflict monitoring module in the anterior cingulate cortex (ACC), which sends an activating signal to the prefrontal areas whenever a conflict is detected. In several simulation studies, they showed that conflict monitoring could account for a variety of behavioral effects like sequential adjustment in an Eriksen flanker task (Gratton, Coles, & Donchin, 1992), trial-type frequency effects in a Stroop task (Tzelgov, Henik, & Berger, 1992), and reactive adjustments in control after erroneous actions in a discrimination task (Laming, 1968).

Given that these tasks need very different implementations of control (e.g., increased focus on the target location in the flanker task vs. increased weighting of color information in the Stroop task), it suggests that conflict monitoring covers unspecific, global occurrences of conflict. It thus might also recruit global control resources, which could then be applied to the specific tasks at hand. Unfortunately, the current evidence for such a global control resource across tasks is mixed at best (for a review, see Schmidt, 2019).

However, there is a solid base of evidence for the modulation of conflict through preceding conflict experience within tasks, which may reflect adaptative control (Gratton et al., 1992; for a recent overview, see Braem et al., 2019). It describes the phenomenon that after an incongruent trial, the performance difference between congruent and incongruent trials is reduced relative to congruency effects after a congruent trial. One possible explanation is that the previous incongruent trial is detected as a conflict, and thus control is enhanced in the current trial. This effect can not only be found in the Eriksen flanker task but also in the Stroop task (e.g., Jiménez & Méndez, 2014). Theoretical explanations assume that cognitive control is a form of decision making, arranged in a hierarchy (Verguts, 2017). The first level tries to optimize behavior (e.g., classify color), and the second level decides which cognitive processes to recruit to do so (e.g., by suppressing distractor stimuli or increased shielding for the target dimension). In this second level, affective processes may come into play, by influencing to what extend cognitive control should be mobilized or which processes should be engaged. More recent theories of cognitive control include affect more explicitly. Shenhav et al. (2017) argue that the basis of exertion of control is a cost-benefit analysis. In this analysis, the aversiveness of mental effort is weighed against the potential benefits of effort allocation. This expected value of control calculation determines the identity and intensity of control signals depending on reward expectancies. Affect may come into play here, by either shifting the perception of the costliness of control or by modifying the value of anticipated rewards. Before I dive deeper into the interaction of affect and cognition, I will go into more detail regarding the nature of affect.

3.2 Core affect

Ever since James (1884) posed the question "What is an emotion?" psychologists have tried to find an answer the majority of emotion theorists could agree on. This quest has not yet been successful, but there are some features that most theorists agree about, for example, that emotions play out over a limited amount of time (seconds to minutes, contrary to moods), and that the capacity for emotions has evolved because it serves specific adaptive functions (Fox, Lapate, Shackman, & Davidson, 2018). Additionally, many psychologists agree that emotions have specific components, like an appraisal of a situation, preparation of specific actions, physiological responses, expressive behavior, and subjective feelings (for an overview of the common ground of emotion theories, see Scherer & Moors, 2019). If you created a piece of music and showed it to a friend who says: "this sounds like Ed Sheeran", this may lead to a wide range of emotions. Depending on your expectation of your friend's response and your evaluation of Ed Sheeran, you might perceive this as a highly unfavorable comparison and appraise it as threatening to your status as a musician. This appraisal could lead to changes in facial expressions (e.g., scowling), physiology (e.g., increased heart rate), subjective experience (e.g., outrage), and could trigger a new action (e.g., questioning your friend's musical expertise or firing back an insult). However, if your evaluation of Ed Sheeran is positive, it could also lead to smiling, satisfaction, and an action like thanking your friend for the compliment. Thus, the initial appraisal concerning expectations is vital in deciding whether a stimulus causes affect and in which direction this goes.

Some theories suggest that emotions are not separate, innate, and universal modules, as proposed by Ekman (1992) but are based on flexibly combined building blocks, most notably on valence and arousal. According to Russell (2003), emotions consist of "core affect", which is a blend of two dimensions, namely valence (pleasurable – unpleasurable) and arousal (activation – deactivation). This is the working definition of affect I will use in this thesis. Newer formulations of this emotion theory state that full-blown emotions are constructed from these smaller building blocks of valence and arousal (Barrett & Bliss-Moreau, 2009). In this view, core affect originates from proprioceptive and neurochemical fluctuations in the body. It arises by integrating information from the environment with information from the body. There is evidence for a brain network, which correlates with subjective ratings of core affect, so this suggests a neural representation of these concepts (Wilson-Mendenhall, Barrett, & Barsalou, 2013). Core affect is used by the organism to prescribe actions to influence these internal and external states in the desired way. It can be experienced explicitly, but people do not necessarily have to be aware of it.

In some conceptions, the construction of emotion categories like fear, anger, or joy arises from active inference based on predictions about the interoceptive feedback of the body and the accompanying prediction errors (Barrett, 2017). The idea here is that the brain's primary function is not feeling or thinking, but to efficiently control the body so it can survive, grow, and reproduce. This process, called "allostasis", means for example, that the brain plans metabolic expenditures by striving for maximum efficiency. For these calculations, the organism uses an internal forward model of the body in its environment. Part of this forward model is the regularities of internal sensations ("interoception"). As an organism does not need to monitor these interoceptions in their raw form, their consequences surface into the conscious experience as affect (valence and arousal).

As an organism encounters the world, previous experiences are used to guide the relevance of new stimuli, and if such a new stimulus matches a pattern of previous core affect, the event will get classified into the same emotion category. An example of patterns of physical sensations getting categorized in affect categories would be the encounter of a sound of metal scratching against metal. This auditory perception may bring to mind previous encounters of that sound, which could be the cocking of a gun in a movie. If you were in a situation like a dark alleyway, this would produce specific physiological changes, which then would be registered as negative affect and, in this case, probably trigger particular actions (e.g., orienting towards the source of the sound). However, a different context like a shooting range might not trigger these physiological changes.

That implies, that affect is not based on a stimulus-response model, but would always come from an interaction of sensory or motor predictions and the event an organism encounters in its environment. Emotions are based on the construction of emotion categories from previous encounters of similar stimuli, responses and effects to assign meaning to sensations (Barrett, 2017), which also explains why the specific content and of these emotion categories can be highly culture-dependent (Mesquita, Boiger, & Leersnyder, 2016).

The function of affect to aid people in interpreting internal states may also matter when it comes to experiencing the output of a conflict monitoring module and deriving adequate action tendencies. People might not have a distinct experience of the output of a conflict-monitoring module, but if the detection of conflict, like other relevant internal signals, is recoded into affect, it could indirectly surface into consciousness and guide behavior. According to Barrett and Bliss-Moreau (2009), core affect supports learning, because when neutral stimuli acquire the capacity to change core affect, they are used by an organism to know what to avoid and what to approach. This gives a first hint towards how affect may play a role in attentional adaptation to conflict, given that conflict stimuli are associated with avoidance (Dignath & Eder, 2015).

In the thesis at hand, I do not look at the interaction of explicitly felt, full-blown emotions, and cognitive control. Instead, I address the link between cognitive control and the regulation of those more primitive affects, the perception of valence and arousal, which serve as precursors to basic emotions like anger, joy, sadness, disgust, surprise, or fear. People do not passively experience and endure affect, but they actively manipulate their environment and their internal states to experience particular affective states.

3.3 Affect regulation

Affect regulation means that people seek to modify or to sustain affective experiences. Even early psychological theories included affect regulation mechanisms, for example, the maintenance of positive affect by repression of aversive content from conscious experience (Freud, 1915). Although the prevailing model of affect regulation was initially created to account for full-blown subjectively experienced emotions, it also seeks to explain lower-level fleeting affective processes (Gross, 2015). It applies the general dynamic of the cybernetic model (Wiener, 1948) to illuminate affective processes by using the idea of feedback loops, inspired by an influential model of self-regulation (Carver & Scheier, 1998). In this view, behavior is goal-directed and feedback-controlled. Goals are set as a reference value, and information from the environment is compared to that goal. Whenever there is a discrepancy, an error signal is generated, and behavior is initiated to reduce this discrepancy. The changed state of the environment is fed back to the comparator with the goal. If there is is still a discrepancy, actions to reduce it are continued. This negative feedback loop is the most common type of self-regulation. However, there are also cases in which people want to increase discrepancy, e.g., in avoidance goals (Carver, 2004). Affect is generated in a second loop that monitors how successful the first loop is at decreasing the discrepancy. Thus, in this new loop, the reference value refers to a desired change in the first loop. The desired change is compared to the actual discrepancy reduction, and the resulting error signal of the second loop is experienced as affect. So if the initial goal is achieved faster than expected, the second loop creates positive affect, while a slower than desired goal achievement leads to negative affect. For instance, the affective consequences of receiving an exam result are not determined by the grade themselves, but by the deviation from expectation, with positive prediction error leading to positive affect and negative prediction error causing negative affect (Villano, Otto, Ezie, Gillis, & Heller, 2020). Affect can be used to adjust the progress towards the goal, for example, by increasing effort. Increasing effort would also raise the rate of goal achievement and thus decrease negative affect, which can already be classified as emotion regulation. However, this only refers integral affect due to the current goal, whereas negative affect often calls for a reprioritization of goals and hamper current goal pursuit, for example, by refocusing attention (e.g., Schmidts, Foerster, Kleinsorge, & Kunde, 2020).

The approach of this self-regulation theory was enhanced by Gross (2015) in an updated formulation of the process model of emotion regulation. In this model, affect regulation consists of hierarchical control loops. The general valuation cycle starts with a state of the world (internal or external), which is perceived by the individual. This perception can lead to a good vs. bad valuation, which can lead to actions that change the state of the world, thus starting the cycle anew (see Figure 1, left side).

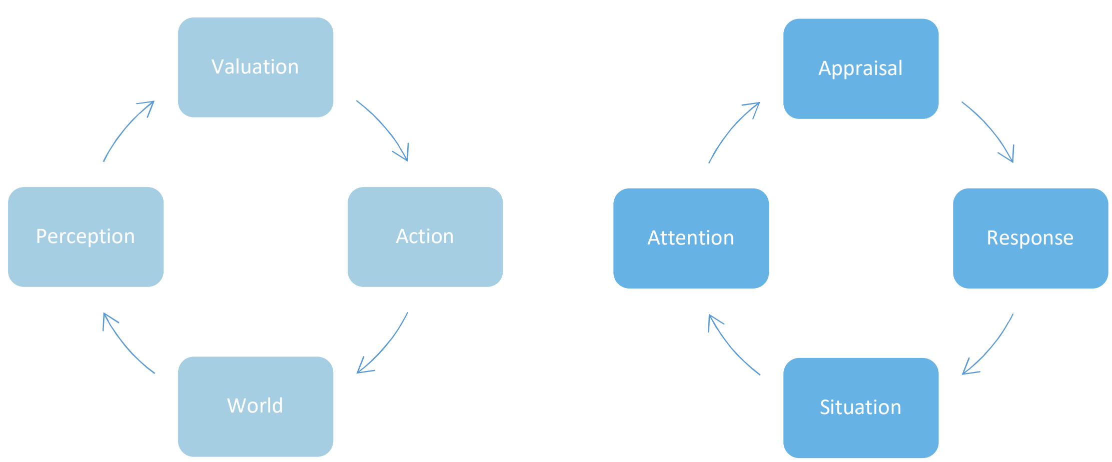

Figure 1. General affect loop on the left and emotion model on the right. Illustration based on Gross (2015).

The action can be aimed at reducing discrepancies between the desired state of the world and the actual state, similar to the model by Carver and Scheier (1998). This loop can be easily applied to the generation of emotion (for the cycle, see Figure 1, right side), which starts with a situation that is perceived and attended to (e.g., listening to your friend compare your song to Ed Sheeran). If it is appraised in a certain way (e.g., "This is not what I want to sound like at all") it triggers a response which changes the situation (e.g., calling out "WTF, man", to signal your displeasure to your friend, for the cycle, see Figure 1, right side). This altered situation starts a new cycle, for example, by a new utterance by your friend ("I like it, though"), which again is perceived and valued (presumably positive this time). Affect regulation occurs when a first-order cycle is evaluated by a second-order cycle as negative or positive, and actions intended to change the first-order cycle are initiated (see Figure 2, left side). This affect regulation action can influence different components of the first-order emotion cycle (see Figure 2, right side). If a situation selection or situation modification strategy is chosen, the goal is to influence the state of the world. For example, you could have avoided sampling this friend's opinion in the first place, to minimize the probability of getting unwanted feedback (situation selection). Or you could kindly inform your friend of all the differences between your song and Ed Sheeran's music, in order to make him change his mind and admit, that they do not sound similar at all (situation modification). Attentional deployment will change the perception of the first-order emotion cycle. This could mean, that you try to drown out any additional commentary by this friend in order to not feel even more annoyed. The valuation can be altered via regulation strategies that engage in cognitive change. You could try to tell yourself: "Actually, Ed Sheeran is a successful musician and a lot of people really enjoy his music, so this is a compliment". If the goal is to alter emotion-related actions, response modulation occurs. You might want to avoid to let your friend know how you feel about this judgment of your song, so instead of yelling "WTF, man", you suppress this emotional expression and just nod with a neutral facial expression. All of these actions can lead to an up or downregulation of emotional intensity or duration or even alter affective quality.

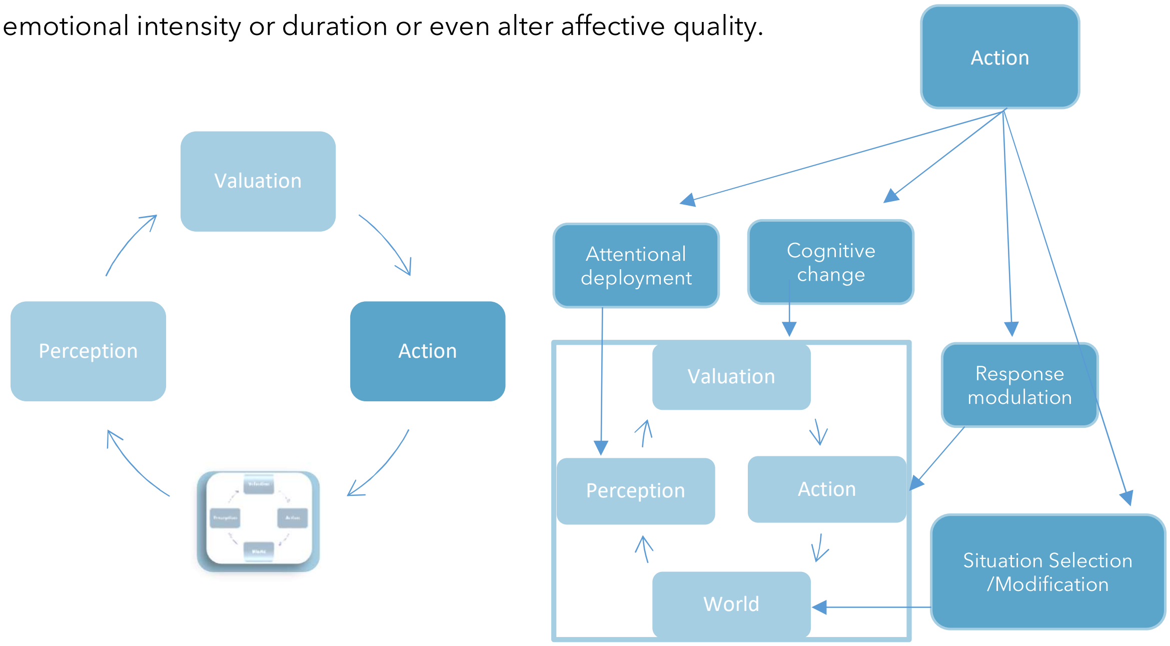

Figure 2. Left side: Affect regulation as a second-order valuation system targeting a first-order emotion generation valuation system. Right side: Possible actions of affect regulation as an output of such a second-order valuation system and their translation into the strategies of the process model of emotion regulation (Gross, 2015). Affect regulation strategies are actions employed by the second-order valuation system to either alter the world (situation selection and situation modification), perception of the world (attentional deployment), valuation of the current situation (cognitive change), or affective actions (response modulation).

Emotion regulation can also be separated into three stages, namely identification (i.e., should affect regulation occur?), selection (i.e., how should affect be regulated?) and implementation (i.e., how do I perform my chosen regulation strategy?). The activation of a goal to modify or maintain the trajectory of emotion is seen as a necessary feature of emotion regulation, especially in contrast to emotion generation (Gross, Sheppes, & Urry, 2011). Notwithstanding, some researchers disagree with this conceptualization of emotion regulation, specifically the importance of representations of goals and emotions. Koole and Veenstra (2015) assert that the reliance on mental representations such as the proposed valuation systems is misguided. Instead, emotion regulation should be regarded as emerging from the interaction of a person and their environment, without resorting to intervening variables that are hard to observe. They allege that the computations of the valuation of an affective situation and choice of an emotion regulation strategy would be too time-consuming to be a realistic explanation. However, they do not provide evidence for this statement. In their view, emotions and their regulation do not need any internal representations like goals or valuations but arise bottom-up from perceiving emotion regulation affordances in the environment. However, most researchers agree that goals or mental representations are needed for affect regulation to occur (Braunstein, Gross, & Ochsner, 2017).

Nevertheless, those goals and valuations do not necessarily have to be represented explicitly. There is a wide variety of emotion regulation processes that are believed to work implicitly and sometimes even automatically (Gyurak, Gross, & Etkin, 2011; Koole & Rothermund, 2011). Implicit emotion regulation can be a by-product of specific actions, for example, shifting your attention away from emotional stimuli (Ma, Abelson, Okada, Taylor, & Liberzon, 2017). Braunstein et al. (2017) proposed a framework of classes of emotion regulation strategies that can be distinguished on two dimensions, namely the nature of the emotion regulation goal (implicit vs. explicit) and the nature of the emotion regulation process (automatic vs. controlled). Automatic types of emotion regulation are explicit-automatic (e.g., placebo, Schwarz, Pfister, & Büchel, 2016) and implicit-automatic (e.g., extinction, Myers & Davis, 2002). Reappraisal is a cognitive change strategy that relies on explicit goals and a highly controlled process (Ochsner, Silvers, & Buhle, 2012). Tasks in which top-down control is employed as a regulatory strategy, but the emotion regulation goal is coincidental are called implicit-controlled and include, for example, the emotional Stroop task (Buhle, Wager, & Smith, 2010). If affect regulation plays a role in cognitive control more generally, it will be predominantly the implicit-automatic type, as the primary goals in these control tasks is not the regulation of emotion, but the optimization of task performance in cognitive tasks.

There are other models of emotion regulation, that use a different approach than the process model of emotion, mainly by emphasizing a distinct aspect of emotion regulation than the strategies. Some focus more on the development of emotion regulation abilities (Thompson, 1994), and especially on persistent maladjusted regulation patterns, so-called emotion dysregulation (Cole, Michel, & Teti, 1994). Interestingly, the development of inhibitory control and functional emotion regulation abilities closely correlates in children, which may hint at a shared basis (Carlson & Wang, 2007). In different prominent models, the emphasis is placed on interindividual measures like the Difficulties in Emotion Regulation Scale to aid clinical applications (Gratz & Roemer, 2004). Here, emotion regulation consists of awareness of emotions, acceptance of emotions, the ability to refrain from impulsive behavior when experiencing emotions, and effective emotion regulation strategies. Nevertheless, all of these models of emotion regulation look at fundamentally similar processes to influence valenced experience and actions, just on other time scales.

Affect regulation is not the only domain in which the process model has been applied. Duckworth, Gendler, and Gross (2016) have suggested that it can also explain self-regulation of behavior, especially for conflict between incompatible actions relating to immediate gratification versus long-term goals, for example, the control of food-related impulses in the pursuit of dieting goals. Duckworth et al. (2016) argue that the choice of situational strategies like situation selection or situation modification is associated with much higher self-regulation success, than the choice of "intra-psychic" strategies like cognitive change or response modulation, which is in line with earlier formulations of self-control (Skinner, 1965). Having defined affect and the current state of research regarding its regulation, I will now move on to review the intersection of cognitive control and affect regulation.

3.4 Cognitive control as affect regulation

Cognitive psychology commonly saw affect as outside of its realm, and especially in the view of the mind as a computer, cognitive and affective processes did not overlap (Neisser, 2014). If psychologists discussed cognition and affect together, then they squabbled about their relative importance. Zajonc (1980) famously argued that affective reactions, such as liking/disliking precede conscious cognitive categorization of stimuli and thus supposedly are among the earliest processes upon encountering a stimulus. Others argued that cognitive appraisals of aspects like goal relevance and goal congruency are necessary for any affective evaluation to occur (C. A. Smith & Lazarus, 1990).

Most arguments for the distinctiveness of affect and cognition do not stand up to scrutiny (Eder, Hommel, & Houwer, 2007). Therefore the view of emotion and cognition as separate and independent systems is probably more a remnant of the history of psychology rather than due to an actual separation in processing or underlying neural architecture. For example, the amygdala, the poster child for emotional brain areas, is also highly involved in cognitive functions like learning, memory, and attention (Phelps, 2006), an indication that a clear neural separation between "emotion" and "cognition" areas does not exist. Similar integration is reported for "cognitive" brain areas like the prefrontal cortex (Pessoa, 2008). Furthermore, if emotion and cognition were based on separate systems, it should be possible for them to run processes in parallel without mutual interference, similar to the separate systems of working memory (Baddeley, 2012). However, there exists a wide range of evidence that affective, as well as cognitive processing, enlist a shared pool of resources (e.g., in a "dual competition", Pessoa, 2009), and if this pool is occupied by affective processing, cognitive processing can not occur or is slowed down (Williams, Mathews, & MacLeod, 1996). For example, Verbruggen and De Houwer (2007) demonstrated that emotional stimuli interrupt the cognitive process of response inhibition in a stop-signal task, which suggests that they are not processed in separate systems.

If affect and cognition are intertwined on many levels of analysis, then there is no point in arguing about the primacy of either one. It will be highly situation-dependent whether a process classified as relatively more cognitive or affective comes first. Thus, in the current thesis, I will not address the dominance of either but will carve out how processes predominantly classified as cognitive interact with processes that are seen as affective. This approach aims for further integration of these two diverging research traditions to gain a more thorough understanding of the human mind.

The interaction of cognition and emotion manifests itself for example in the influence of cognitive control on affect regulation, through the control of attention towards affective stimuli (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013), and their reinterpretation (Ochsner & Gross, 2005). The opposite direction can also be observed, as emotions influence cognitive control in a variety of ways (Pessoa, 2009). Affect may not only be incidentally involved, but it could play an integral part in the control of cognitive conflict (affective signaling hypothesis; Dignath, Eder, Steinhauser, & Kiesel, 2020), and for this to occur, there has to be an association between conflict and affect. Evidence supporting this hypothesis comes from the finding that cognitive conflict gives rise to negative affect. Dreisbach and Fischer (2012) combined color-word Stroop task stimuli with an affective priming paradigm (APP). The idea behind this paradigm is that affective stimuli activate the respective affect dimension (positive or negative) and make it easier to categorize subsequent stimuli of the same affect dimension and harm categorization of stimuli of the opposite affect dimension. Viewing incongruent Stroop trials facilitated the evaluation of negative pictures and words, whereas the observation of congruent Stroop trials decreased reaction times to positive targets. This finding indicates that incongruent Stroop stimuli could be inherently more negative than congruent Stroop stimuli. In a similar study using an affect misattribution procedure (AMP, Payne, Cheng, Govorun, & Stewart, 2005), observing incongruent Stroop stimuli caused people to judge following neutral words and Chinese pictographs more negatively than observing congruent trials (Fritz & Dreisbach, 2013). Negative affect evoked by conflict stimuli must have been falsely attributed to subsequent neutral stimuli, thereby causing a more negative judgment of them.

Additional evidence for the interwovenness of cognitive control and negative affect comes from neuroscience. It has been suggested that pain, negative affect, and cognitive control may be used in a domain-general way to deal with uncertainty based on findings that these functions are all correlated with activation in the anterior midcingulate cortex (Shackman et al., 2011). In line with this, participants with lesions in the anterior midcingulate cortex exhibit reduced performance in a Stroop task as well as deficits in recognizing emotional faces, presumably due to the causal role this brain area plays in both domains (Tolomeo et al., 2016). Additionally, there is evidence from brain imaging studies that suggest that there may be some common mechanisms in the control of cognitive interference and emotional interference (Banich et al., 2009). One possibility is that if inhibition has an affective component, there is no actual conceptual difference between the control of cognitive and affective interference.

Even if conflict is associated with negative affect, why should you assume that affect has a functional role to play in cognitive control? There is evidence that affect influences attentional control. For example, the induction of positive affect decreases performance in a flanker task, presumably due to a broadening of attention (Rowe, Hirsh, & Anderson, 2007). Furthermore, sustained affective states like moods can influence conflict adaptation (van Steenbergen, Band, & Hommel, 2010). Participants who received negative feedback on a fake intelligence test show more substantial conflict adaptation than participants who received positive feedback (Schuch, Zweerings, Hirsch, & Koch, 2017). It could be the case that a negative mood facilitates the processing of mood-congruent material leading to better conflict detection or participants in a negative mood might be more motivated to regulate their affect and thus to engage in increased adaptation to conflict.

Already Narziss Ach proposed that an *Unlustgefühl* (feeling of disinclination, i.e., negative affect) is beneficial to the realization of willful actions, as long as the negative affect imposes the imagination of the performance of an action (Analyse des Willens, p. 360/361). In line with this, affect induced by conflict may not merely be a by-product of perceiving conflict, some evidence also points towards the idea that it may be necessary for the emergence of behavioral adaptations to conflict. It has been proposed that the congruency sequence effect can be observed because conflict induces negative affect, which in turn signals the need for enhanced control and thus leads to better performance in the subsequent conflict trial (Dreisbach & Fischer, 2015). The finding that performance-unrelated rewards between trials eliminated the congruency sequence effect supports this assumption (van Steenbergen, Band, & Hommel, 2009). Positive affect induced by random rewards might have canceled out negative affect produced by conflict and thus eliminated the signal to enhance cognitive control. That indicates that adaptation to conflict could be the result of the affective consequences of conflict. However, such a modulation has not been replicated in the Simon task, in which conflict arises due to stimulus-response interference (Dignath, Janczyk, & Eder, 2017; Stürmer, Nigbur, Schacht, & Sommer, 2011).

Nevertheless, in tasks like the Flanker and the Stroop task, where conflict is mostly due to interference between features of the stimulus (stimulus-stimulus conflict), affective modulations of conflict adaptation occur (although their direction is not always consistent, e.g., Padmala, Bauer, & Pessoa, 2011). Thus, even in relatively early cognitive conflict, affect is involved, and the regulation of cognitive control may be less "cold", as previously thought (e.g., Peterson & Welsh, 2014, who regard the Stroop task as an example for a prototypical "cool" task). That is in line with research on higher-order cognitive functions like reasoning in which affect is believed to be beneficial as long as it is integral (affect is induced by the target stimuli), but not when it is incidental (unrelated to the target material; Blanchette & Richards, 2010).

If affect depends on predictions, the perception of internal states and their allostasis, as Barrett (2017) proposed, then this can fit nicely with conflict monitoring theory. If humans generally predict a conflict-free environment, then a conflict signal detected by a conflict monitoring module is a prediction error. These conflict signals, on the one hand, are subsequently consciously perceived as affect. On the other hand, they may lead to adaptions of attention with the goal to reduce this state of prediction error, which may result in conflict adaptation. Whether this affect is causal in creating conflict adaption or whether it just results from the same source remains unclear (Dignath et al., 2020).

Some researchers argue that experience of conflict is necessary for conflict adaptation (Desender, van Opstal, & van den Bussche, 2014, but see Foerster, Pfister, Reuss, & Kunde, 2017). This conflict experience might just be a conscious experience of negative affect caused by conflict, and indeed Fröber, Stürmer, Frömer, and Dreisbach (2017) found that when they measured people's subjective experience of the previous trial in a Simon task, this led to increased suppression of automatic response activation in an electroencephalography (EEG) study, which mirrors the conflict adaptation phenomena. However, even if negative affect is not consciously experienced, it may still occur (Berridge & Winkielman, 2003), and exert influence on control behavior (Abrahamse & Braem, 2015).

A different mechanism for the influences of affect on cognitive control might arise due to the associations of affect with effort (Gendolla, 2012) and effort with control (Kahneman, 1973). According to the implicit-affect-primes-effort model, affective states become associated with task demand states, and thus bi-directional activations develop (Gendolla, 2012). Consequently, specific affective primes can activate mental representations regarding the ease and difficulty of a task. For example, happiness becomes associated with low task difficulty over time, and thus happiness primes should result in lower perceived task demand (Silvestrini & Gendolla, 2019). The exerted effort is dependent on task demands. People increase effort with increasing task demands, as long as they perceive success to be possible, then effort collapses (Motivational intensity theory, Brehm & Self, 1989).

Consequently, when task demands are low or moderate, negative mood states lead to higher mobilization of effort than positive mood states, and priming of sadness and fear causes higher effort exertion (Silvestrini & Gendolla, 2019). Applied to cognitive conflict, this framework predicts that conflict leads to increased negative affect, which primes the perception of greater difficulty, which leads to increased effort. That might explain the conflict adaptation effect. Additionally, due to the capacity limitation of cognitive control, exerting effortful control may be assigned a high cost and, for this reason, merely recruited if the benefits outweigh those costs (Shenhav et al., 2017). This calculation may partially depend on affective signals as an input. Negative affect could signal the intrinsic cost of effort exertion and thus an increased need for control resources. The allocation of control resources might be done in a way that maximizes reward (e.g., by avoiding error) and avoids excessive effort due to permanently high states of control. If this were true, then the optimal allocation of effortful control may be governed by affect regulation goals, which is in line with the idea that control has a close relationship to motivational incentives (Botvinick & Braver, 2015).

All of these ideas suggest that it may be fruitful to apply the extended model of emotion regulation to explain conflict adaptation. The first-order valuation system would consist of the state of the word (e.g., an incongruent stimulus, like the word red printed in yellow, see Figure 3), which is perceived as a conflict by a conflict monitoring module. The valuation system gives out a negative evaluation ("this is aversive"), which gives rise to action impulses to get rid of the aversive state, for example, the amplification of the relevant color information in the subsequent trial. Conflict adaption serves in this context as a mechanism of affect regulation to reduce the aversive effect of future conflict. The main conceptual difference to the conflict monitoring theory (Botvinick et al., 2001) is the crucial involvement of the valuation system. If, for some reason, the valuation component would rate a conflict as neither good nor bad, no adaption should take place. This prediction is in line with the finding by van Steenbergen et al. (2009), in which conflict adaptation was eliminated by the presentation of positive stimuli between trials. Furthermore, if this were true, conflict adaptation could be just one of many possibilities to regulate the affective impact of conflict. As with higher-level emotion regulation, regulation of transient affect may occur on all points of the timeline of such an event.

Apart from the potential causal involvement of affect regulation processes in conflict adaptation, this framework may be fruitful in shedding light on cognitive control of behavior in response to conflict. If the control of conflict creates negative affect, several possible strategies can be employed to deal with it, attacking at different time points in the affective episode. To regulate the emerging negative affect, people could engage in situation selection, for example, by choosing to avoid conflicting situations. They could also engage in situation modification, for example, by making conflicting stimuli less conflicting. Attentional deployment could be used to reduce conflict monitoring, to perceive less conflict. The valuation of conflict could be changed by reappraising conflict in a way that makes its experience less aversive (e.g., by trying to think of it as a situation in which you can prove yourself). Finally, the response could be modulated, for example, by increasing the intensity of a control process.

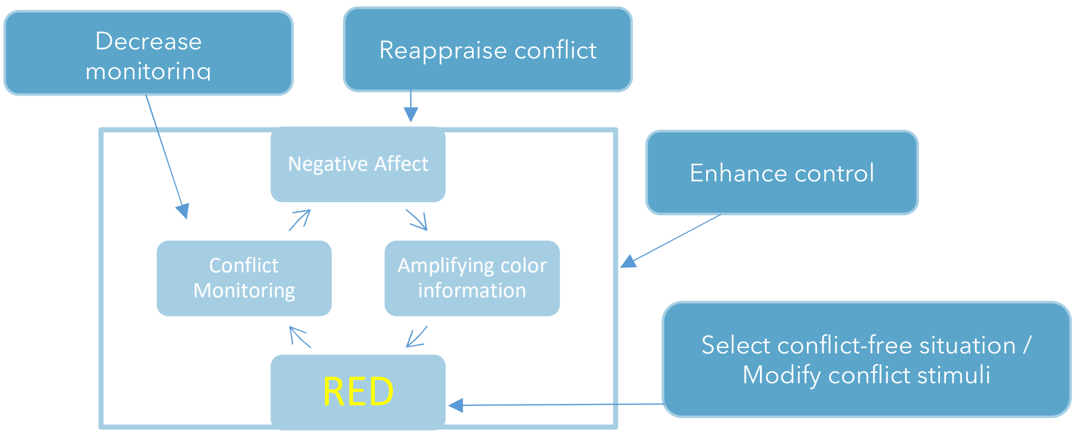

Figure 3. Possible regulation strategies to deal with an instance of control of conflict in a Stroop task.

If you look at three different stages that correspond to the valuation systems proposed by (Gross 2015), regulation processes of conflict can appear at all points of dealing with conflict. In the identification stage, the monitoring of conflict could be up- or downregulated to either decrease or increase subsequent adaptation processes. If conflict adaptation works like affect regulation, then there should be no behavioral adaptation, if the initial appraisal of conflict turns out to not identify it as something negative. In the selection stage, an affect regulation strategy is picked from all potential strategies, which include control enhancement, conflict avoidance, or task disengagement. The implementation stage could then include refocusing of attention if control enhancement is chosen as an affect regulation strategy, or it could include the preferential choice of situations without conflict if conflict avoidance were chosen as a strategy.

One of the predictions resulting from this framework is that the more negative affect a conflict stimulus generates, the more control should be recruited to deal with said conflict. Probably only until a certain point, at which negative affect becomes overwhelmingly intense, a realignment of higher-order goals will lead to actions that decrease exertion of control (e.g., task disengagement or even quitting the experiment, Gendolla, 2012). Furthermore, to be control enhancing, the affect has to either stem from task-relevant stimuli (Kanske & Kotz, 2011) or be misattributed to them. Otherwise, it will not produce control behavior.

In cognitive control tasks, affect regulation is typically not the primary task goal, and may not even be explicitly activated, but could become active by the mere encounter of an affective situation. Some goals in relation to emotional experience may be chronically active. In general, people have a prohedonic motivation, which means that they indicate that they want to maintain or enhance positive affect when they experience it and dampen negative affect (Riediger, Schmiedek, Wagner, & Lindenberger, 2009). In experience sampling studies, most regulation attempts are in a pro-hedonic direction (English, Lee, John, & Gross, 2017). However, it has been argued that these observed emotion regulation behaviors might be driven more by eudaimonic motives than hedonic ones (Ortner, Corno, Fung, & Rapinda, 2018). Nevertheless, the general regulation goal is to increase positive affect and reduce negative affect. For most strategies, this affect regulation goal is in line with other goals like solving the task in a way that will result in enhanced performance.

I used the extended process model of emotion regulation (Gross, 1998b) as a framework to investigate the involvement of affect in cognitive control, namely whether adaptation to conflict may be instances of affect regulation and, as such, a case of "hot" rather than "cold" cognition. I tested whether strategies that people use to handle and modulate emotions can be used to cope with cognitive conflict. In particular, I investigated in three experiments, if and when people take the anticipation of conflict-strength of a situation into account to shape their future environment, as they do with the anticipation of emotions. In another seven experiments, I examined whether situation modification influences responding in a cognitive conflict task, which role the predictability of the specific modification plays, and if affective changes come with these modifications. In the final empirical chapter, I tested directly whether the extended process model of emotion regulation can be used to explain conflict adaptation by manipulating the valuation component of conflict.

4 Situation Selection

One strategy to diminish negative affect caused by conflict would be to select situations with low levels of conflict if possible. A first hint that people are motivated to avoid conflict comes from a study that showed that conflict resulted in preference and facilitation of avoidance responses compared to approach responses (Dignath & Eder, 2015). However, do agents also select situations according to the anticipated magnitude of cognitive conflict? Evidence for conflict avoidance comes from the finding that when participants could freely choose between two univalent tasks, they were more likely to switch tasks after a conflicting trial, i.e., select a different situation (Dignath, Kiesel, & Eder, 2015). This discovery shows that situation selection can be one strategy people use to deal with conflict. In the following experiments, I will test more directly whether people avoid conflict situations, and whether they learn to do so automatically or whether they need explicit information about the association of their actions with the incongruency of upcoming situations. These experiments have been previously published (Schmidts, Foerster, & Kunde, 2020).

4.1 Introduction

Imagine you enter a train, and you see to your left a train car filled with aggressive drunk people screaming at the top of their lungs and on the right, a train car filled with people quietly staring into their devices. Most people will probably pick the right train car because they anticipate that spending time there will elicit less negative feelings. Choosing situations according to their likely emotional impact is an emotion regulation strategy called situation selection (Gross, 2015). When the goal of emotion regulation is a short-term hedonic one, situation selection predicts that people prefer to expose themselves to situations in which they feel pleasure instead of exposing themselves to aversive situations. For instance, when people are forced to select a picture to look at, they are more likely to select joyful pictures than neutral pictures or disgusting pictures (Markovitch, Netzer, & Tamir, 2017).

Recently, it has been suggested that cognitive conflicts, which occur when sensory input indicates competing behavioral responses, are registered as aversive signals (Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013). These cognitive conflicts play an essential role in the regulation of behavior by triggering cognitive control (Botvinick et al., 2001; Egner, 2017). Affect involved in cognitive conflict may even lie at the heart of adapting cognitive control (Dignath et al., 2020). Following the logic of a situation selection strategy, if a cognitive conflict has an aversive component, people should also prefer situations they expect to be poor rather than rich in cognitive conflict. Consequently, if given a choice, they should be more likely to select a low-conflict situation than a high-conflict situation.

Imagine that once you have reached the station, you had to pick a connection tube to your final destination leaving one of two otherwise equivalent platforms. At one platform, all tubes were running to your desired destination. At the other platform, tubes were running to your destination but also to other destinations. Which one would you choose? To avoid an unpleasant choice, you might tend to select the platform with an unequivocal destination. The current study puts this assumption of situation selection as a means to regulate affect induced by cognitive conflict to test in the laboratory.

There is some tentative evidence that people avoid conflict, such as when they can freely choose between two univalent tasks, they are more likely to switch tasks after a conflicting trial, i.e., they select a different situation (Dignath et al., 2015). Interestingly, switching tasks in these experiments did not actually reduce the chance of conflict in the upcoming trials. Conflict probability was 50/50 after repeating and after switching a task. Another piece of indirect evidence comes is that people prefer to move a joystick away from conflict stimuli, rather than to move it towards these stimuli (Dignath & Eder, 2015; Schouppe, De Houwer, Ridderinkhof, & Notebaert, 2012). This finding suggests that conflict has a motivational component that triggers avoidance as soon as the conflict is registered, supposedly because conflict is aversive.

In line with this, people are also more likely to choose a context that is associated with a low level of conflict, than to choose a context that is associated with a high level of conflict (e.g., Desender, Buc Calderon, van Opstal, & van den Bussche, 2017). The most persuasive evidence for avoiding conflict in anticipation comes from a study of Schouppe, Ridderinkhof, Verguts, and Notebaert (2014), who asked participants to do a vocal Stroop task. In a learning phase, a category cue signaled whether the trial had a conflict probability of 80% or 20%. In a choice phase, participants had to pick one of these conflict contexts by clicking on the category cues before the appearance of the Stroop trial. Participants showed a preference for the low-conflict category. Two explanations can account for the preference of the low-conflict context. First, experiencing the aversiveness of cognitive conflict could have served as a learning signal, biasing action choices implicitly. A similar mechanism has been proposed to account for attentional adjustments to conflict (van Steenbergen et al., 2009). The second possibility is that people avoid conflict deliberately based on their explicit knowledge of the relation of category cue and conflict signal.

In the current study, I wanted to figure out whether the experience of cognitive conflict is sufficient to bias choice behavior, or whether explicit knowledge about the contingencies between choices and the congruency of a situation is necessary. Therefore, participants selected situations with actions that had the primary purpose of solving a Stroop task. I assigned two correct response keys to each color. One of these keys produced a high-conflict situation in the next trial, while the other key led to a low-conflict situation. In three experiments, I tested whether people implicitly learn to avoid response keys that lead to conflict. In Experiment 1, key-pairs were associated with an 80% and a 20% chance, respectively, of conflict in the upcoming trial. In Experiments 2 and 3, each key generated a certain level of congruency with 100% probability. Experiment 3 tested the impact of explicitly informing participants about the key-congruency assignment on choice behavior.

I assumed that people prefer to use keys that produce a low-conflict environment and avoid those that produce high conflict.

4.2 Experiment 1

Methods

Participants solved a Stroop task by classifying whether a word was displayed in red, blue, or yellow with button presses. Stroop stimuli were presented in the center of a 22' screen in the font Gill Sans MT in size 72. Each trial started with a fixation cross for 500 ms, followed by the stimulus, which was presented for 1500 ms or until a response was given. In case of an incorrect response, participants received an error message for 1000 ms. When they missed the response deadline, an error message was displayed for 1500 ms. After an inter-trial interval of 500 ms, the next trial started.

I created congruent trials (e.g., BLUE in blue) and incongruent trials (e.g., BLUE in red) from the words RED, BLUE, and YELLOW. For each color, participants were instructed to choose between two possible keys. Whenever a word was displayed in red, they could either press the *F* key with their left index finger or the *J* key with their right index finger. The yellow font color mapped to *D* and *K* (middle fingers) and the blue font color to *S* and *L* (ring fingers). Participants were told to decide spontaneously which of the two possible keys to press, that they should not just press one of the two keys over the course of the experiment and that they should not press both in the same trial. Furthermore, I urged participants to respond with high speed, as soon as they saw the stimulus. Note, that I did not tell them to press each key equally often because such an instruction would have the potential to strongly bias response choices and obscure effects of the probability of the upcoming congruency.

The response keys differed in the probability of congruency in the following trial (see Figure 4*)*. One key lead to a subsequent incongruent trial in 80% of the cases and to a congruent trial in 20% of the cases. The other key produced 80% congruent trials and 20%

incongruent trials. As an illustration: If participants pressed the *F* key to the red font color, the following trial had a probability of 80% to be congruent, whereas if they pressed the *J* key the following trial had a 20% probability of being congruent. The mapping of keys to congruency probability was counterbalanced across participants. Participants could have none, one, two, or all three keys of one hand associated with a high probability of congruency in the next trial.

Participants conducted a training phase in which they were told to get accustomed to all the response keys. The training ended adaptively when they pressed each key at least once and encountered at least 20 trials. If they did not press each key at least once, the training ended after 50 trials. Afterward, they went through 600 Stroop trials. At last, they were asked debriefing questions, i.e., whether they used strategies and whether they detected any differences between the keys and filled out an emotion regulation questionnaire (Gross & John, 2003). This exploratory interindividual measure did not lead to any correlation in any of the experiments, so I will not discuss it further.

I planned the sample sizes of Experiments 1 and 2 based on an arbitrary, medium-sized effect of d_z = 0.5. I decided to strive for a power of .80 to detect this effect size in a within-subjects design with an alpha of 5%. According to the power analysis I did in R (version 3.5.1, package "pwr"), a sample size of 33 participants meets these criteria. Due to counterbalancing, I rounded up to 34 participants. I did not replace excluded participants. All of the following experiments were conducted in accordance with the local ethical guidelines and the Declaration of Helsinki. According to the ethical guidelines of the German Society for Psychology (DGPs) and the regulations of the local ethics committee of the Institute for psychology of the faculty for human sciences of the Julius-Maximilians-University of Würzburg, in-depth review by an ethics committee is not mandatory, providing that participants give signed informed consent; data are collected anonymously, and the study has no foreseeable negative impact on participants. Our ethics committee has screened these criteria, and I received a statement that for a study with these characteristics, no such approval is necessary. Informed consent was obtained from every participant prior to the start of the experiments. I excluded three participants due to their answers to the debriefing questions. One participant figured out the hypothesis, which is impractical for our goal to test the implicit influence of conflict. Another participant indicated that he or she ignored the instruction by sticking to one hand for a time, and the third participant indicated that he or she just used the right hand. Including those participants does not change the results in a meaningful way. Of the remaining sample of 31 participants, 21 self-identified as female and ten as male. Twenty-seven were right-handed (four left-handed), and the mean age was 28 years (standard deviation, *SD* = 7 years).

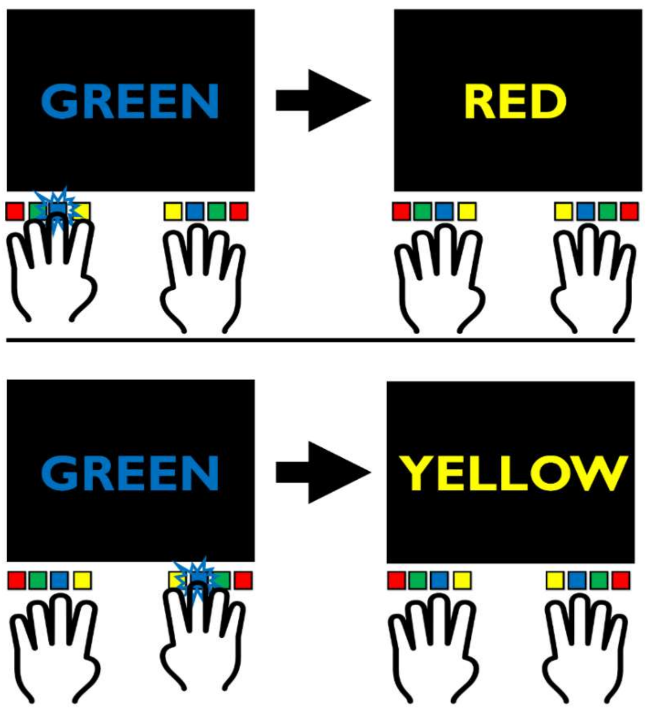

Figure 4. In this exemplary trial of Experiment 3, a correct keypress with the left hand produced an incongruent stimulus in the subsequent trial (upper panel). Pressing the correct key with the right hand produced a congruent Stroop stimulus in the next trial (lower panel). In Experiment 1 and 2, participants solved a three color-word Stroop task, whereas, in Experiment 3, they solved a four color-word Stroop task. In all three experiments, every color was mapped to two keys, which determined the congruency of the following trial. Only in Experiment 3 was subsequent congruency always fully mapped to one particular hand. In Experiment 1, each key determined the subsequent congruency with an 80% probability, in Experiment 2 and 3 with a 100% probability.

Results

I included all Stroop trials in the error analysis. For the analysis of response times, I only included correct trials that did not deviate more than 2.5 *SD*s from their individual cell mean. Note that the number of trials in each cell is unequal, because participants determined by their choices how many congruent and incongruent trials they encountered. Participants committed more errors in incongruent Stroop trials (*M* = 8.70%, *SD* = 4.54%), than in congruent Stroop trials (*M* = 6.10%, *SD* = 4.25%), $t(30) = 4.47$, $p < .001$, $d_z = 0.80$. They also responded slower in incongruent Stroop trials (*M* = 591 ms, *SD* = 65 ms), than in congruent Stroop trials (*M* = 536 ms, *SD* = 57 ms), $t(30) = 11.67$, $p < .001$, $d_z = 2.10$.

For the key choice analysis, I only included correct trials. Moreover, I also decided a priori to exclude the first 100 trials as learning trials for the contingency between keys and congruency probability. This number seemed reasonable to be able to learn contingencies but was otherwise arbitrary. I calculated the percentage of choosing the key that produces a congruent trial with an 80% probability (low-conflict key). This percentage should be higher the more people prefer creating congruent situations to creating incongruent situations. Participants chose the low-conflict key in 51.66% (*SD* = 5.19%) of the trials (see Figure 5), which did not differ significantly from chance level performance, $t(30) = 1.78$, $p = .086$, $d_z = 0.32$. To test whether these results support the null hypothesis I calculated a one-sample Bayesian *t*-test comparing the mean of the low conflict choices to the value of 50 using JASP 0.9.0.1 (JASP Team, 2018).

Contrary to null hypothesis significance testing, this analysis tests whether the observed data is more likely under the null hypothesis than under the alternative hypothesis. If the resulting Bayes Factor is larger than 1, the observed data pattern is more likely under the null hypothesis of "no difference from 50, and if it is smaller than 1, the probability of the data is higher under the alternative hypothesis. This resulted in a BF_{01} of 1.288. Given that Bayes Factors between than 1 and 3 are commonly assumed to provide only anecdotal evidence, the current data remain inconclusive (Rouder, Speckman, Sun, Morey, & Iverson, 2009; Schönbrodt & Wagenmakers, 2018).

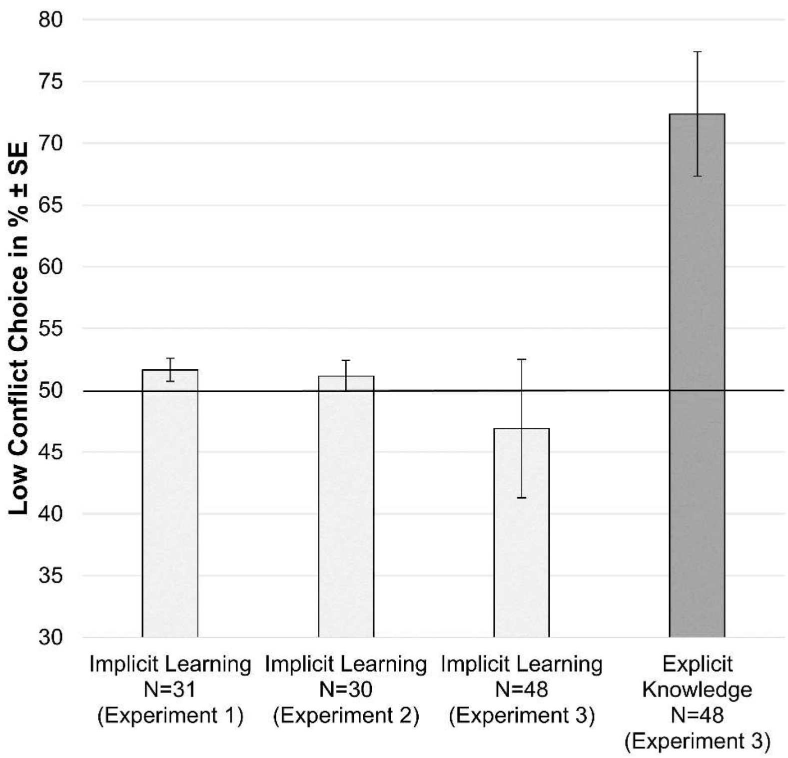

Figure 5. Mean percent of choices for the key associated with low or no conflict in the subsequent trial. The black line represents chance level performance. Error bars show the standard error (SE) of the mean.

Discussion

Participants showed a significant congruency effect in errors and response times, which means that they experienced conflict. However, contrary to my predictions, they did not choose the low-conflict key significantly more often than the one that is more likely to produce incongruent trials. Accordingly, there was no evidence for a situation selection strategy to regulate affect originating from conflict. Participants either did not experience conflict as negative and thus saw no need to regulate affect, or they did experience conflict as negative but did not choose situation selection as an emotion regulation strategy. Alternatively, they may have failed to learn the contingency between their choice behavior and conflict implicitly. However, the Bayesian analysis revealed that there was also no evidence in support of the null hypothesis. A possible explanation is that the association between key choice and subsequent congruency was too weak, with 80% probability being too low to bias participants' choices. To test this, I conducted an additional experiment in which each key was associated with a 100% probability of experiencing either congruent or incongruent trials.

4.3 Experiment 2

Methods

To keep it frugal, I only refer to aspects of Experiment 2 that deviated from Experiment 1. The contingency between the press of a particular key in the current trial and congruency in the upcoming trial was 100%. I excluded the possibility that subsequent congruency could sometimes be mapped exclusively to a single hand. Instead, each hand was assigned keys that created conflict-free trials and keys that created conflicting trials.

The research assistant recruited one more participant than planned. Thus a new sample of 35 participants took part, of which I had to exclude four participants who ignored the instruction to use both hands and did the entire main part of the experiment by using either the left or the right hand. I excluded one additional participant due to an excessive amount of errors (*SD* > 3.3 above the mean error rate of all participants). The 30 participants included for analysis had a mean age of 24 years (*SD* = 3 years). Twenty-six were right-handed, (four left-handed). Five of them self-identified as male and 25 as female.

Results

The exclusion criteria for the analyses were the same as in Experiment 1. The error rate in the Stroop task was higher for incongruent Stroop trials (*M* = 8.89%, *SD* = 6.17%), than for congruent Stroop trials (*M* = 6.54%, *SD* = 3.37%), $t(29) = 2.74$, $p = .010$, $d_z = 0.50$. Participants were slower in incongruent Stroop trials (*M* = 564 ms, *SD* = 53 ms), than in congruent Stroop trials (*M* = 525 ms, *SD* = 47 ms), $t(29) = 8.34$, $p < .001$, $d_z = 1.52$. Participants chose the low-conflict key 50.33% (*SD* = 5.43%) of the time (see Figure 5), which did not differ from chance level performance, $t(29) = 0.33$, $p = .744$, $d_z = 0.06$. Furthermore, I calculated a Bayesian one-sample *t*-test against the test value of 50, which resulted in a

BF_{01} of 4.891, which suggests moderate evidence for the null hypothesis (Schönbrodt & Wagenmakers, 2018). I test whether the observed data pattern provides support for the null hypothesis, so higher Bayes Factors represent stronger support for the null hypothesis of “no difference from 50”.

Discussion

Again, participants showed interference due to conflict, but this did not influence their choice behavior. Even with a 100% contingency between key choice and upcoming congruency, there was no preference for keys that created congruent trials over keys that created incongruent trials. Thus, I again could not find evidence for the avoidance of conflict by a situation selection strategy. This result could either indicate that people do not avoid conflict, or that they do avoid conflict, but are unable to learn associations between their choices and the congruency of subsequent situation implicitly. To examine whether conflict influences choices if people do have explicit knowledge of the relationship between choice behavior and conflict, I conducted an additional experiment.

4.4 Experiment 3

In Experiment 3, I tested whether people do prefer low-conflict environments when they have explicit knowledge about the consequences of their actions, even if they do not use conflict signals implicitly to adjust situation choice behavior. To this end, I first replicated the previous experiments, but after completing 400 trials, I informed participants about the contingencies between key choice and subsequent congruency. Afterward, they completed an additional set of 140 Stroop trials. Moreover, to rule out a possible confound of stimulus set size, I employed a four color-word Stroop with four congruent and four incongruent stimuli. In the previous studies, there were only three individual congruent stimuli and six individual incongruent stimuli, which could have influenced choices. I also eliminated another influence on choice behavior, namely response repetitions, by splitting the four-color / four response task into two sets of two-color / two-response tasks that alternated (inspired by Schmidt & Weissman, 2014, who used this to control for contingency learning and feature integration confounds in congruency sequence effects).

Methods

To keep it frugal, I again only refer to aspects of Experiment 3 that deviated from the former experiments. To facilitate implicit learning, congruency production was mapped to hands, so that one hand produced a congruent trial, whereas the other produced conflict in the next trial (see Figure 4). Each key fully determined the congruency of the subsequent trial. As in the previous experiments, participants started with an implicit choice block, but crucially, after about two-thirds through the experiment, they were informed about the contingency between key presses and subsequent congruency. After I provided them with this explicit knowledge, they underwent an additional choice block.

Further changes to the previous experiments concerned the instructions and appearance. I eased the restriction to free choice ("do not use one key exclusively for the whole experiment"), so the remaining instruction was that they should just use whichever key they spontaneously liked more at the moment, but should not press both at the same time. As they technically stuck to the instructions, I did not exclude participants who exclusively used one hand, contrary to the previous experiments, and did not preregister their exclusion. Excluding them does not change the results of the following analysis in a meaningful way.

Additionally, I animated the stimuli after responding by showing them for 20ms at ¾ of the original size, 20ms at ½ the size, 20ms at ¼ the size and by starting the stimulus presentation after the fixation cross with a presentation of the stimulus at ½ the size for 20 ms. I wanted to introduce flow to the task and nudge people to see a connection between the trials (the E-prime files for the experiment are freely available at the *Open Science Framework*, https://osf.io/pmjh3/).

To control for stimulus and response repetitions, I added the color green. Participants had to choose between pressing the *A* key or the *L* key (pinky fingers) for stimuli displayed in red, the *S* key or the *K* key (ring fingers) for blue stimuli, the *D* key or the *J* key (middle fingers) for the color green and the *F* key or the *H* key (index fingers) for the color yellow. I grouped red and yellow together, while green and blue formed the second group. Incongruent trials were constructed by using the distractor word within a group: RED displayed in yellow / YELLOW displayed in red and BLUE displayed in green / GREEN displayed in blue. Trials alternated between stimuli from these two groups. In other words, a trial containing either a red or a yellow stimulus was always followed by a trial containing only blue or green as stimuli features.

As a consequence, there were no stimulus repetitions and no response repetitions. After 400 trials, participants were asked if they noticed any differences between the hands and whether they used any strategies. Afterward, they were informed which hand produces congruent trials and which hand produces incongruent trials. Then I asked them to do another 140 trials.

An additional change to the previous experiments is that I tested a higher number of participants to increase statistical power to detect an effect. My power analysis aimed at the detection of differences between the implicit and the explicit condition, and I hypothesized that the preference for choosing low-conflict situations should be higher in the explicit than implicit condition, allowing for directed testing. Again, I had no indication of how big this effect might be if it exists, thus, relying on an arbitrary medium-sized effect of $d_z = 0.5$. I recruited 48 participants, which gives me a power of .96 to detect such an effect in a one-sided paired *t*-test, with an alpha level of .05, according to the package "pwr" (R 3.5.2). I had to exclude one participant due to an exceptionally high error rate (*SD* > 5.59). I replaced this participant, so my final sample consisted of 48 participants with a mean age of 25 years (*SD* = 4), of which ten self-identified as male and 38 as female. Nine of them indicated they were left-handed, the other 39 indicated they were right-handed. A preregistration of the main hypothesis, statistical analyses, and data exclusions, as well as the raw data and the R scripts for all of the following statistical analyses, are freely available (Schmidts, 2019).

Results

For the Stroop analysis, I only included participants who provided at least five trials in each cell. For the response time analysis, I used correct Stroop trials that did not deviate more than 2.5 *SDs* from their individual cell means. These criteria lead to the exclusion of eight participants from the response time analysis. For the choice analysis, I did include all participants following my preregistration, because I did not deem these exclusions necessary for this analysis. However, excluding participants who failed the inclusion criteria for the response time analysis from the choice analysis does not change the results in a meaningful way.

Participants did not commit significantly more errors in incongruent trials (*M* = 14.06%, *SD* = 12.10%), than in congruent trials (*M* = 10.18%, *SD* = 5.71%), $t(39) = 2.00$, $p = .052$, $d_z = 0.32$. They responded slower to incongruent trials (*M* = 809 ms, *SD* = 230 ms), than to congruent trials (*M* = 651 ms, *SD* = 106 ms), $t(39) = 4.25$, $p < .001$, $d_z = 0.67$.

As in the previous experiments, I included only correct trials and excluded the first 100 trials for the implicit choice analysis. I tested choice frequencies within the implicit and explicit condition in two-sided *t*-tests as in the previous experiments and compared them between these conditions in a one-sided *t*-test in accordance with my preregistration. In the implicit choice condition, participants chose the low-conflict keys in 46.90% (*SD* = 38.75%) of the cases (see Figure 5), which did not differ from chance level performance, $t(47) = -0.55$, $p = .582$, $d_z = -0.08$. I also calculated a Bayesian one-sample *t*-test which tested whether the data are different from the test value of 50, which resulted in a BF_{01} of 5.515 which is in line with moderate support for the null hypothesis (Note that I did not test my directed hypothesis, but whether the data supports chance level performance). In the explicit choice condition, participants chose the low-conflict keys in 72.37% (*SD* = 34.89%) of the cases, which was significantly higher than chance level performance, $t(47) = 4.44$, $p < .001$, $d_z = 0.64$. The Bayesian one-sample *t*-test resulted in a BF_{01} of 0.002, which is in line with very strong support for the alternative hypothesis (Schönbrodt & Wagenmakers, 2018).

The preference for low-conflict keys was significantly higher in the explicit choice condition than in the implicit choice condition, $t(47) = 5.13$, $p < .001$, $d_z = 0.74$.

Internal meta-analysis

To further explore whether there could be a preference for low-conflict key choices in the implicit conditions, I computed a meta-analysis over all three experiments ($k = 3$, $n = 109$), with the Cohen's d values, the standard errors of these d values according to formula 12.21 / 12.22 in Borenstein, Cooper, Hedges, and Valentine (2009), and an r of 0.5. I chose a random-effects-model and used the packages "meta" (Schwarzer, 2007) and "metafor" (Viechtbauer, 2010) in R (version 3.6.0). An I^2 of 32% suggests low heterogeneity between the studies. According to this meta-analysis, the estimated effect is $d = 0.08$, 95% CI [-0.43; 0.58].

Discussion

Even a relatively obvious contingency between a key choice and the congruency it produced in an upcoming trial, did not promote an adaptation of choice behavior in the current experiment. I expected participants to engage in an affect regulation strategy, based on the experienced aversiveness of the conflict signal, to avoid upcoming conflict. I did not observe such regulation strategies when participants were given the opportunity to implicitly learn the association between their choice behavior and the amount of conflict in the following situation[1]. However, when participants received explicit information that one

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[1] As mentioned in the methods sections, I did a manipulation check of awareness by asking participants several questions, either at the end of the Experiment (1 & 2) or at the end of the implicit block (Experiment 3). One of those questions inquired whether participants discovered any differences between the two keys they could use to respond to a specific color. If they answered yes, they were asked to provide the differences they discovered in an open question. In Experiment 3, 39 participants answered that they did not discover any differences between the keys. Of the 9 participants who did, I looked at the differences they indicated and there were 4 participants whose answers could be classified as having figured out the contingency (e.g., "for the right

hand produces a congruent trial, while the other produces an incongruent trial, people showed a preference for choices that created congruent situations over choices that created conflict situations.

4.5 Summary discussion situation selection

Inspired by situation selection as an emotion regulation strategy (Gross, 2015), the current study examined whether situation selection also is a means to regulate cognitive conflict by avoiding it. In three experiments, however, participants did not spontaneously choose actions that produced conflict-free situations more often than actions that produced conflicting situations. They only preferred actions leading to conflict-free situations, when they were explicitly told about the association of their action and the subsequent congruency.

This clear distinction between implicit and explicit sources of situation selection in the context of cognitive conflict could help to reconcile diverging results in the relevant literature. People did not preferably choose the low-conflict keys unless explicitly informed about the consequences of doing so, whereas, in the study by Schouppe et al. (2014), people chose low-conflict contexts over high-conflict contexts. One probable explanation for this discrepancy might be that contrary to my design, all the participants might have become consciously aware of the relationship between context and conflict in their study. In Schouppe et al. (2014), the choice action (a mouse click), was more salient because it was

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responses, the color fitted with the word"). An exploratory analysis shows that their mean low conflict choice in the implicit condition was 65%, which appears to deviate from chance performance (a *t*-test is not significant, but severely underpowered due to the small sample size). However, these participants are included in the reported main Bayes analysis, which provides evidence for the hypothesis that overall performance is about chance level. So if anything, the test for the implicit condition in Experiment 3 is very liberal and should have found an effect if there was one. I did not preregister any exclusion of these participants in Experiment 3, so I am hesitant to change my reported analysis in hindsight.

separated from the action that was used to solve the Stroop task (vocalization), whereas in the current experiment these aspects were implemented in a single action (button press). Therefore, people might have only assigned the instrumental goal of classifying the color to this specific action but might not have used that specific action for other goals (feeling good).

Furthermore, the temporal separation between situation selection and the cognitive control task might have freed cognitive resources. Solving the primary Stroop task might have taken so much attention, that there was no room to implement implicit secondary goals like affect regulation. However, the current results also stand in contrast with findings that show that people avoid cognitively demanding situations, even when they are not aware of the experimental manipulation (Kool, McGuire, Rosen, & Botvinick, 2010). On the other hand, there are studies using a block-wise instead of a trial-wise choice design that come to similar conclusions as my study (Desender et al., 2017). Furthermore, a recent study, using a task-switch design, showed that people need to be consciously aware of cues signaling cognitive effort to avoid it (Dunn, Gaspar, & Risko, 2019). It is not entirely clear why the methodological differences between the current studies and studies using a demand selection task yield such different patterns of results. These discrepancies present an interesting avenue for future research.

Participants showed a clear bias for low-conflict situations when they had explicit knowledge about the effects of their key choices, but they still only chose it in about 72% of the trials. If conflict is aversive, why did they not avoid it in 100% of the trials? For once, even though incongruent trials are more aversive than congruent trials and thus influence choices, their absolute aversiveness may still be relatively low (e.g., compared to IAPS pictures). Additionally, people may be reluctant to go exclusively for the easy and pleasant alternative and might be willing to expose themselves to some amount of aversive stimulation in order to "keep things interesting" (Wilson et al., 2014). However, to put it in context, this result is in line with other experiments that examine how effortful cognitive processes influence free choices. In experiments on voluntary task switching, participants switch tasks in about 30 to 40% of cases, rather than keep on repeating the task, even though switching tasks is much more effortful (Fröber & Dreisbach, 2016) and has been shown to be aversive (Vermeylen, Braem, & Notebaert, 2019). Furthermore, regarding experiments on situation selection, in Experiment 1 by Markovitch et al. (2017), participants voluntarily chose to look at disgusting images rather than at a blank screen in 38% of the cases. This data suggests that even if given a choice, people do not fully avoid goal-irrelevant aversive stimuli.

One limitation of the current study is that I did not measure affect directly. I base the assumption that Stroop conflicts are implicitly viewed as negative on a variety of previous studies. Multiple studies have shown that incongruent Stroop trials can prime negative affect in affective priming paradigms (Dreisbach & Fischer, 2012; Pan et al., 2016) and affect misattribution procedures (Fritz & Dreisbach, 2013). Furthermore, when people are asked explicitly, stimuli associated with incongruent Stroop trials are liked less compared to the stimuli associated with congruent Stroop trials, no matter whether people were just primed or whether they actually responded (Damen, Strick, Taris, & Aarts, 2018). However, there is some opposing evidence, according to which the resolution of conflict can be perceived as positive (Schouppe et al., 2015). Thus, it might be the case that even though participants initially experience negative affect when encountering conflict, the successful resolution of conflict leaves them with an overall more positive experience, and thus there is no motivation to avoid conflict situations. Having said this, objective measures (electromyography of the facial corrugator muscles), suggest that participants experience negative affect after correctly solving conflict (Berger, Mitschke, Dignath, Eder, & van Steenbergen, 2020).

Additionally, recent studies find that Stroop conflict is associated with negative affect, no matter whether participants have to respond or not (Goller, Kroiss, & Ansorge, 2019). An integrative review on the interplay between conflict and affect concludes that the hypothesis that conflict triggers negative affect "is well supported by empirical evidence" (Dignath et al., 2020). Based on these previous works, I feel comfortable in my assumption that Stroop conflict was perceived as negative in the current study. Aside from that, if conflict were not explicitly aversive, why would participants avoid it in the explicit condition?

Another alternative explanation for the absence of implicit conflict avoidance in choices is that conflict is indeed perceived as aversive, but for some reason, participants do not strive to feel good and thus have no motivation to engage in regulating their emotions. There is some evidence that people sometimes expose themselves to unpleasant feelings in order to attain a goal. Tamir and Ford (2009) found that participants chose to face fear-inducing music and memories in order to help them play a threatening video game more successfully. However, this explanation seems unlikely in the current study because there was no instrumental benefit to engage with conflict. On the contrary, choosing conflict trials led to increased errors and response times and thus to worse task performance overall. This indicates that increased choices for conflict in pursuit of task benefits are an improbable explanation for the absence of a choice asymmetry. Besides, this does not explain that people do choose actions that produce conflict-free situations, as soon as they gain explicit knowledge of the consequences of their choices.

It is also conceivable that conflict triggers emotion strategies implicitly, but that situation selection does only operate explicitly. A free choice between two actions may be governed by higher-order decisions, which might not be under the influence of an implicit, aversive conflict signal. Affect regulation in response to a conflict may differ to emotion regulation in response to full-blown emotion, by predominantly depending on implicit affect regulation (Gyurak et al., 2011). Affect regulation strategies that rely on conscious deliberation, like situation selection and cognitive change, may only be susceptible to an influence of conflict when explicit knowledge exists about the relationship between an action and the amount of conflict it produces. Other, less explicit affect regulation processes like situation modification and attentional deployment, on the other hand, may have a larger influence on conflict, even in the absence of such explicit knowledge. Indeed there is evidence that affect regulation processes similar to situation modification have an influence on conflict tasks: In a similar Stroop task as the one used here, people are more inclined to change a conflict-laden situation to a conflict-free one, than they are to change a conflict-free situation to a conflict-laden one (see chapter Situation Modification).

In light of this, another explanatory approach is that people might have had the goal to regulate their affect in a way that makes them feel better, but tried to regulate affect in a different way, or not at all. Accordingly, instead of engaging in situation selection, they might have attempted other emotion regulation strategies such as cognitive change. Ghafur, Suri, and Gross (2018) argue that there are two puzzles related to emotion regulation, firstly, that people often do not regulate their emotions even when they have the opportunity to do so and secondly, that they frequently do not use the most adaptive emotion regulation strategy. In their view, orienting attention and action readiness might be responsible for that. They argue that when people do not apply enough attention to the value of the regulation of a situation, they will not take any action. This might be the case in the current study.

Given that the primary task already occupies the attentional system, there might be no cognitive capacity left to evaluate the action choice on their anticipated affective consequences. People might just have failed to see the benefits of trying to engage in affect regulation. That might have changed when they were told about the association between keypress and subsequent congruency. After that, they might have focussed attention on affect regulation and started choosing actions that produced conflict-free and thus less aversive situations.

In conclusion, people do not necessarily avoid actions that produce cognitive conflict unless they are consciously aware of the consequences of their action choices. Nevertheless, the explicit preference for actions that select conflict-free situations adds to the body of evidence showing that conflict has an aversive component.

The choice of a situation might be governed by explicit choices that may not be influenced by an implicit, aversive conflict signal. In this regard, the affect regulation I postulate in this thesis may differ from the emotion regulation that is described by Gross (1998b). Affect regulation in reaction to cognitive conflict, may be a more implicit process (Gyurak, Gross & Etkin, 2011). Thus, it may be the case that higher-order decision making like response selection is unaffected and more determined by unrelated factors. This view suggests, that there might be a division between explicit emotion regulation strategies and implicit ones and that conflict may trigger implicit ones, rather than explicit ones. That would suggest that some affect regulation phenomena are more likely to be associated with conflict than others. The most explicit strategies are situation selection and cognitive change. Those might be less susceptible to an influence of conflict. Situation modification, attentional deployment, and response modulation, on the other hand, may work on a more implicit level and accordingly have a greater connection to conflict. Therefore, I explore whether situation modification influences responding in a Stroop task, in the following section.

5 Situation Modification

5.1 Introduction

In this chapter, I examined whether another emotion regulation strategy, situation modification, plays 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, these processes can also work implicitly (Gyurak et al., 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 world" (p. 10). I assume that the desired state of the world for most people means relatively more positive than negative affect (Freud, 1940), so conflict situations should trigger action impulses that decrease the negative affect they cause. I 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), I 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 following experiments, I demonstrate that actions are 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, I 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. Furthermore, I explored whether these facilitations are associated with affective changes.

5.2 Experiment 4

I used a standard conflict-inducing task, the Stroop task. The participants' 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. Figure 6).

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 *incongruent modification condition,* actions always produced (or retained) 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 current situations to more negative ones, responses that produce incongruency should be harder to generate than responses that produce congruency. I 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, I 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. Therefore, 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 I could expect, I used the number of participants that were available to me for each experiment. In Experiment 4, forty participants took part in exchange 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 was recorded. They were also excluded, which left a sample of 37 participants for analysis (M_{age} = 29.41, SD_{age} = 9.12; 23 female and 14 male; 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 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 session of twelve trials in which the exact stimulus they reacted to was presented as an action-product after their response. Afterward, 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 a white background. The stimulus stayed until participants responded or 1800ms went by. When 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 stimuli 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 random order. Between the two blocks, there was a self-paced break.

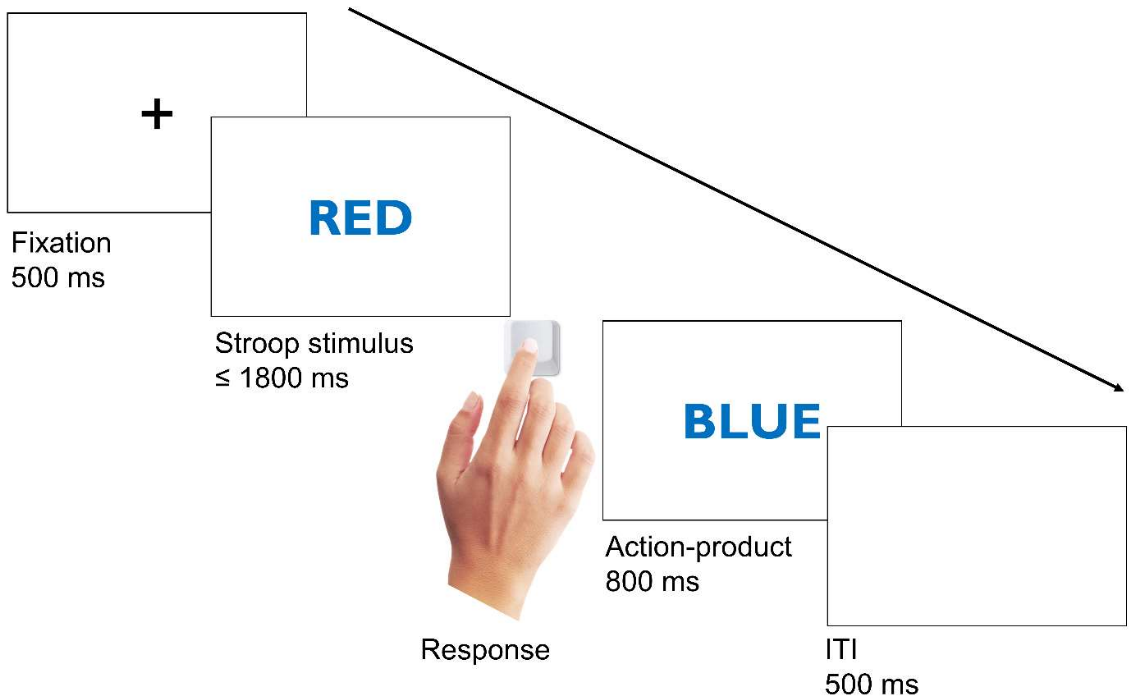

Figure 6. An exemplary trial sequence of an initially incongruent stimulus in the congruent modification condition in Experiment 4. The word RED printed in blue changes towards the word BLUE printed in blue after the delivery of a correct response.

Results

Data Treatment

As it takes some time to learn that responses consistently produce certain action-products, I 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, I excluded all erroneous trials for RT analyses (4.0%). I also excluded outliers, i.e., RTs that deviated more than 2.5 SDs 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).

Response times

Participants responded faster to congruent stimuli (*M* = 523 ms, *SD* = 68 ms) than to incongruent stimuli (*M* = 579 ms, *SD* = 92 ms, see Figure 7), $F(1, 36) = 73.45$, $p < .001$, $\eta_p^2 = .67$. 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, $F(1, 36) = 2.63$, $p = .113$, $\eta_p^2 = .07$.

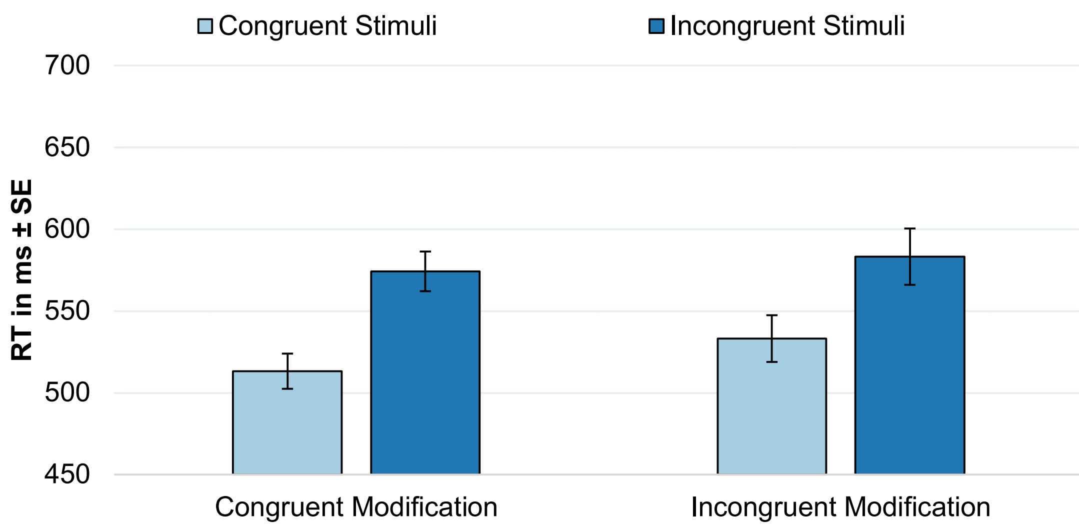

Figure 7. Mean RTs of Experiment 4, separated by stimulus congruency *and* modification *block. Error bars represent standard error of the means (SE).*

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 interaction with *stimulus congruency* reached significance, *F*s < 1.

Discussion

Confirming my predictions, Experiment 4 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 with the congruency of the resulting action-product. A matching account 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 (2nd bar from the left in Figure 7) and the relative slowdown of congruent Stroop trials in the incongruent *modification* condition (3rd bar in Figure 7) added up to produce the main effect of *modification* condition.

Altogether, Experiment 4 supports the assumption that affect regulation processes like situation modification influence responding in conflict tasks. After a closer look at my paradigm, I came up with a possible limitation to the idea that mere change in congruency produces the *modification* effect. To foreshadow the remainder of the chapter, 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 and 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 my 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, 2019). 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, similar to cognitive conflict (Levy, Harmon-Jones, & Harmon-

Jones, 2018). One might thus argue that cognitive conflict is just a specific type of cognitive inconsistency, causing negative affect, whereas unpredictability is another one.

Hence, the results of Experiment 4 could 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 I found. To pinpoint the role of uncertainty, I ran two experiments. One in which uncertainty was eliminated (Experiment 5) and one in which it was introduced in all conditions (Experiment 6). Additionally, I manipulated the congruency of the action-products and their predictability orthogonally in Experiment 7. In Experiment 8, I replicated the basic effect and excluded a possible alternative explanation for the results of Experiments 4 and 7. In Experiments 9 and 10, I probed whether the modification effect is associated with measurable changes in affect.

5.3 Experiment 5

Experiment 5 controlled for *modification* predictability by aligning the number of possible action-products in both *modification* conditions. If the modification effects of Experiment 4 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. Consequently, 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 5 was mostly equivalent to Experiment 4 except that I 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 4. Which action-product word was associated with a certain stimulus was counterbalanced across participants. For example, whereas in Experiment 4, 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. Accordingly, for each participant, the exact identity of action-products was, in principle, predictable in all cells. Thirty-three participants took part (M_{age} = 27.45, SD_{age} = 7.66; 25 female and eight male; 30 right-handed), of which 17 started with the *congruent modification* block and 16 started with the *incongruent modification* block.

Results

Data Treatment

I used the same exclusion criteria as in Experiment 4. 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).

Response 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 4, a significant interaction of *stimulus congruency* and *modification block* emerged, $F(1, 32) = 4.84$, $p = .035$, $\eta_p^2 = .13$, (see

Figure 8*)*. This interaction was caused by a larger congruency effect in the *congruent modification* block, (Δ = 72 ms, SD = 55 ms) than in the *incongruent modification* block (Δ = 54 ms, SD = 37 ms).

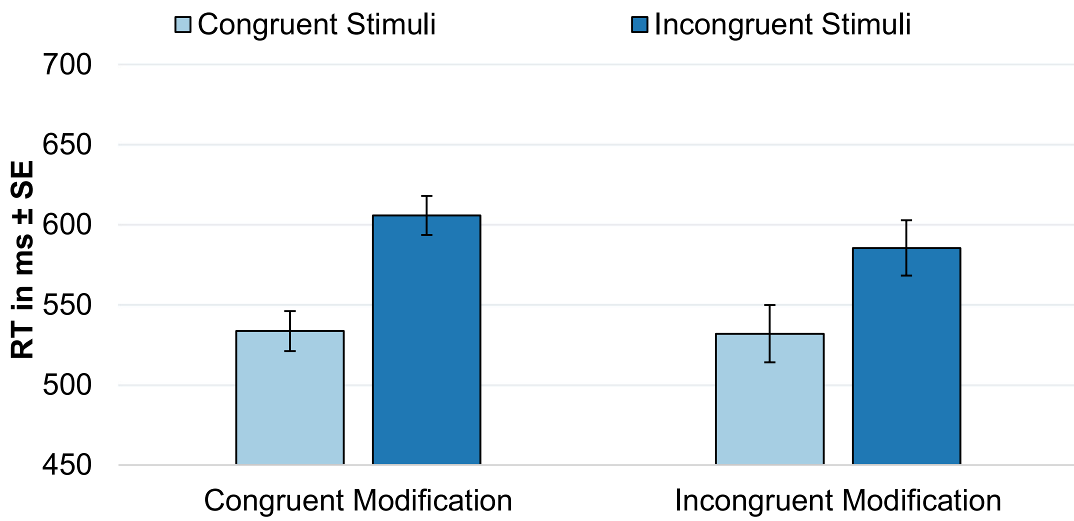

Figure 8 Mean RTs of Experiment 5 separated by stimulus congruency *and* modification *block. Error bars represent standard error of the mean (SE).*

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

I did not find an effect of *modification* when I 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 4. The results of the current experiment suggest uncertainty as an important determinant in situation modification. Contrary to Experiment 4, I found a diminished Stroop effect in the *incongruent modification* condition. I am reluctant to base strong inferences on this effect since it did only replicated in one of the other experiments of this chapter. 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 increased recruitment of proactive control in this experiment. This speculation would need further support, which was beyond the scope of the present study (for an additional debate of this, see the discussion of Experiment 10).

5.4 Experiment 6

In Experiment 6, I did not eliminate effect uncertainty as in Experiment 5 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. Therefore, 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 I expect no difference.

Methods

All action-products consisted of a different font color, and a different color word than the one participants just responded to. Furthermore, the distractor word of the stimulus never became the font color of the action-product. This segmentation 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 (M_{age} = 24.65, SD_{age} = 3.58; 18 female; 25 right-handed) of which 13 started with the *congruent modification* block and 13 started with the *incongruent modification* block.

Results

Data Treatment

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

Response Times

RTs for congruent stimuli (M = 633 ms, SD = 111 ms) were lower than for incongruent stimuli (M = 743 ms, SD = 152 ms; see Figure 9), $F(1, 25) = 92.77$, $p < .001$, $\eta_p^2 = .78$. There was neither a main effect of *modification block,* $F < 1$, nor an interaction, $F(1, 25) = 1.68$, $p = .207$, $\eta_p^2 = .06$.

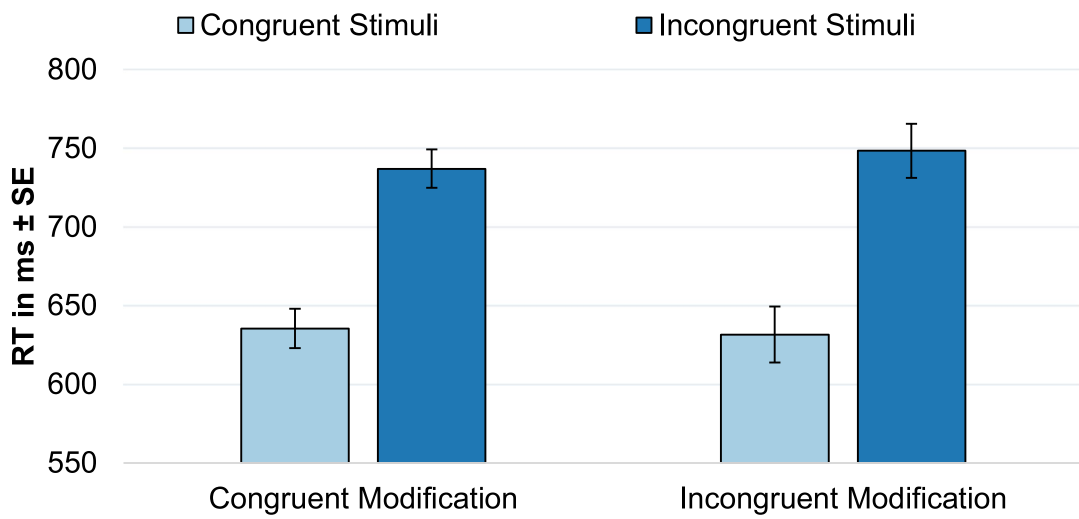

Figure 9 Mean RTs of Experiment 6 separated by stimulus congruency *and* modification *block. Error bars represent standard error of the mean (SE).*

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

I did not observe a *modification* effect when both *modification* conditions were equally uncertain concerning the specific effect 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 four-, instead of three-color word Stroop task. Additionally, given that there was never any relationship between the stimulus and the dimensions of the action-product, participants might be better to separate them into different event files and thus avoid any influence of the anticipation of upcoming incongruency. Furthermore, it could be the case that they learn to shield any attention from the action-product, thus diminishing its influence.

To conclude, when response-triggered stimulus modifications are equally certain (Experiment 5) or uncertain (Experiment 6), there seems to be no benefit of modifying stimuli to congruent over incongruent events. These results suggest that action production benefits occur only when these actions produce events that are both congruent and predictable. Of course, it might also be the case that the modification effect demonstrated in Experiment 4 was just a spurious observation. Therefore, I aimed to replicate the congruency modification benefit and test directly its dependency on prediction certainty in Experiment 7.

5.5 Experiment 7

Experiment 7 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, I 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

Using an alpha level of 0.05, the detection of an effect of the size of the modification condition in Experiment 4 (d_z = 0.36) with a power of 0.8 would need 61 participants, according to G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007). Due to counterbalancing, I chose to recruit 60 participants for this experiment (M_{age} = 27.01, SD_{age} = 7.60; 39 female and 21 male; 56 right-handed).

The general trial procedure was the same as in the previous experiments. I used a Stroop task with the colors red, yellow, and blue. Participants underwent four blocks. 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 led to congruent action-products, in the other two to incongruent action-products. The congruent-predictable block was exactly as the congruent modification block in Experiments 4 and 5. 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.

Contrary to the incongruent-predictable modification condition in Experiment 5, stimulus color always changed in Experiment 7 (e.g., RED in red turned into BLUE in yellow as well as BLUE in red into BLUE in yellow). In contrast, participants merely changed the distractor word in Experiment 5 (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, I reduced the number of trials per block to 180. Another adjustment was aimed at directing participants' attention towards the events they produced. These were nominally task-irrelevant and could theoretically be ignored, which means that the congruency of produced events may not be registered at all (though at least the data of Experiment 4 speak against this possibility). Therefore, I 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, I excluded errors (7.0 %) and outliers (2.7%). The data were submitted to a 2 x 2 x 2 ANOVA with the factors *stimulus congruency* (congruent vs. incongruent), *modification congruency* (congruent vs. incongruent), and *modification predictability* (predictable vs. unpredictable). I 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).

Response Times

The main effect of *stimulus congruency* was significant (see Figure 10), $F(1, 59) = 210.44$, $p < .001$, $\eta_p^2 = .78$. 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).

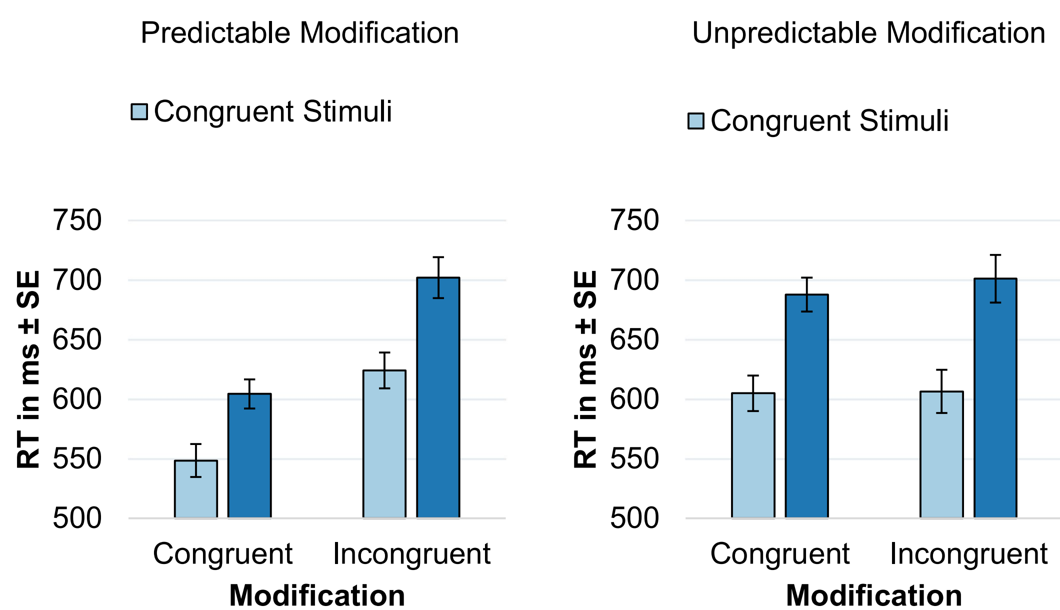

Figure 10 Mean RTs of Experiment 7 separated by modification predictability *and plotted as a function of* stimulus congruency *and* modification congruency*. Error bars represent standard error of the mean (SE).*

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, $t(59) = 6.77$, $p < .001$, $d_z = 0.87$. When it was unpredictable, there was no difference between the congruent (*M* = 646 ms, *SD* = 125 ms) and the incongruent (*M* = 652 ms, *SD* = 129 ms) modification conditions, $t(59) = 0.62$, $p = .535$, $d_z = 0.08$.

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 (Δ = 69 ms, *SD* = 38 ms), than in the *incongruent modification blocks* (Δ = 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 (Δ = 66 ms, *SD* = 44 ms), than in the *unpredictable modification* blocks (Δ = 88 ms, *SD* = 53 ms). The three-way interaction of *stimulus congruency*, *modification congruency* and *modification predictability* was not significant, $F < 1$.

Additionally, I calculated an exploratory analysis that sought to examine whether responding to conflict stimuli in the predictable, congruent modification condition (*M* = 604 ms, *SD* = 116 ms) differed from RTs to congruent stimuli in any of the other conditions (predictable-incongruent modification: *M* = 624 ms, *SD* = 122 ms; unpredictable-congruent modification: *M* = 605 ms, *SD* = 115 ms; unpredictable-incongruent modification: *M* = 607 ms, *SD* = 111 ms). There was no significant difference (all *p*s >.080), which means that even though responding to a conflict was not faster than responding to congruent stimuli, participants were able to respond as quickly to a 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, $t(59) = 5.68$, $p < .001$, $d_z = 0.73$. 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, $t(59) = 0.72$, $p = .475$, $d_z = 0.09$. 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 *congruent modification* blocks ($\Delta = 2.35\%$, $SD = 3.84\%$), than in *incongruent modification blocks* ($\Delta = 4.28\%$, $SD = 4.89\%$). Neither the interaction of *stimulus congruency* and *modification predictability* nor the three-way interaction were significant, Fs < 1.

Discussion

As predicted, I found an interactive influence of the congruency of a to-be-produced *modification* and the (un)predictability of that *modification* on response latencies. Additionally, this interaction also manifested in the error rates. The strength of the *modification* manipulation is nicely illustrated by comparing the second and third bar from the left in Figure 10: 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. These data show 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 the facilitation of responding. Furthermore, I 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 the unpredictability of the upcoming action-products has a detrimental impact on cognitive control. The influence of action-product congruency is different from Experiment 5, where the Stroop effect was larger in the incongruency production condition, so I am 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. I believe this is an interesting observation that underlines the general assumption of a close link between conflict and emotion regulation and certainly warrants further investigation.

Interestingly, I found no difference between predictable congruent versus incongruent modification blocks in Experiment 5, whereas I did in Experiment 7. One difference between the experiments is that in Experiment 7, 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 5, 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 versus incongruent modification conditions in Experiment 7 but not in Experiment 5. To test whether this is the main factor driving the results found in Experiment 4 and 7, I devised Experiment 8.

5.6 Experiment 8

In the previous studies, 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 always 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. Alternatively, the repetition of some aspects of the situation (either color or word dimension) or a connection of the correct response with the action-product, might be a necessary condition for participants to process the stimulus and the action-product as belonging together (e.g., in an event-file; Hommel, 2004b). This would mean that when there is no target dimension repetition or association between the target feature of the action-product and the afforded response, participants never learn to bind stimulus and action-product. Consequently, the anticipation of the congruency of the action-product would not influence responding to the stimulus.

While I cannot rule out this account through the present data, it seems unlikely given previous research. Specifically, Hommel (2004a) 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. However, to rule out this alternative explanation experimentally, I conducted a study in which predictable, congruent action-products that do not match the correct answer are compared to unpredictable and incongruent action-products that also do not match the correct answer. 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 can produce modification effects in the absence of any dimensional overlap between target stimulus and action-product or response and action-product. Accordingly, I expected a main effect of modification congruency. Response times for congruent, predictable modification blocks should be lower than for incongruent, unpredictable modification blocks. The preregistration for this hypothesis is publicly available on the Open Science Framework (https://osf.io/zub73).

Methods

Based on a power analysis carried out in R (package "pwr"), I planned to recruit 66 participants, but in the end, due to a misunderstanding, the research assistance recruited 69, and I decided to use all of the data. One of those participants had to be excluded due to an excessive amount of errors. Thus the final sample consisted of 68 participants, with a mean age of 26 years (SD_{age} = 8 years, $range_{\text{age}}$ = 18 – 61 years), of which 51 identified themselves as female, the other 17 as male. To make sure that the anticipation of a correct response does not influence responding, I chose separate stimulus sets for the target stimuli and the action-products. Participants responded to congruent and incongruent stimuli in the colors red, yellow, blue and green, by pressing D, F, J, or K on a standard keyboard, with distractor words consisting of the same color words. They underwent a training block of 24 trials in which they got accustomed to this color to key mapping and the Stroop task in general. After this, they were informed that in the following blocks, their response would create a new color word. This action-product could consist of the words gray, pink, brown, and orange, displayed in their respective colors (see Figure 11).

Furthermore, they were informed that at certain points in the experiment, they would be asked in catch trials which specific action-products they could produce in this block. Note that there was never any dimensional overlap between target stimuli and action-products and that the action-products were irrelevant to solving the primary Stroop task. As in the previous studies, participants started each of the modification blocks with 64 learning trials. Afterward, they were asked to indicate for all 16 individual target stimuli which action-products they were associated with. Following this, they carried out 216 Stroop trials. Subsequently, they performed the same sequence of a learning block, contingency questions, and experimental trials for the converse modification block. For further detail, the experiment file is publicly available on the Open Science Framework (https://osf.io/yaes7/).

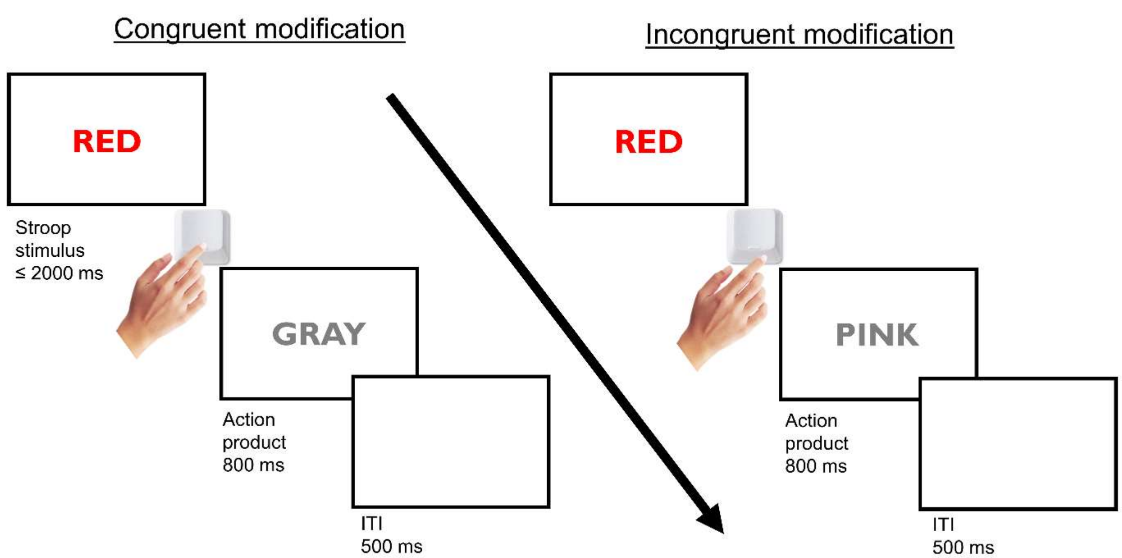

Figure 11. Experimental conditions in Experiment 8. In both conditions, the target color changes from the stimulus to the action-product (red to gray). In the congruent modification condition, the change is always predictably towards a congruent action-product, whereas in the incongruent modification

condition, it is towards one of three incongruent action-products, thus unpredictable in specific identity of the action-product.

Results

Data Treatment

For the RT analysis, I excluded errors (8.28 %) and outliers (2.5%). The data were submitted to a 2 x 2 ANOVA with the factors *stimulus congruency* (congruent vs. incongruent) and *modification* (congruent/predictable vs. incongruent/unpredictable). I expected a main effect of *modification*. The two-way interaction was 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).

Response Times

There was a main effect *stimulus* congruency, as RTs for congruent stimuli (M = 726 ms, SD = 106 ms) were lower than for incongruent stimuli (M = 820 ms, SD = 116 ms, see Figure 12), $F(1, 67) = 227.51$, $p < .001$, $\eta_p^2 = .77$. There was also a significant main effect of *modification,* $F(1,67) = 8.92$, $p = .004$, $\eta_p^2 = .12$. Participants responded faster when they created a congruent/predictable action-product (M = 759 ms, SD = 123 ms) than when they created an incongruent/unpredictable action-product (M = 787 ms, SD = 110 ms). The factor s*timulus congruency* did not interact with the factor *modification*, $F(1,67) < 0.01$, $p = .963$, $\eta_p^2 < .01$.

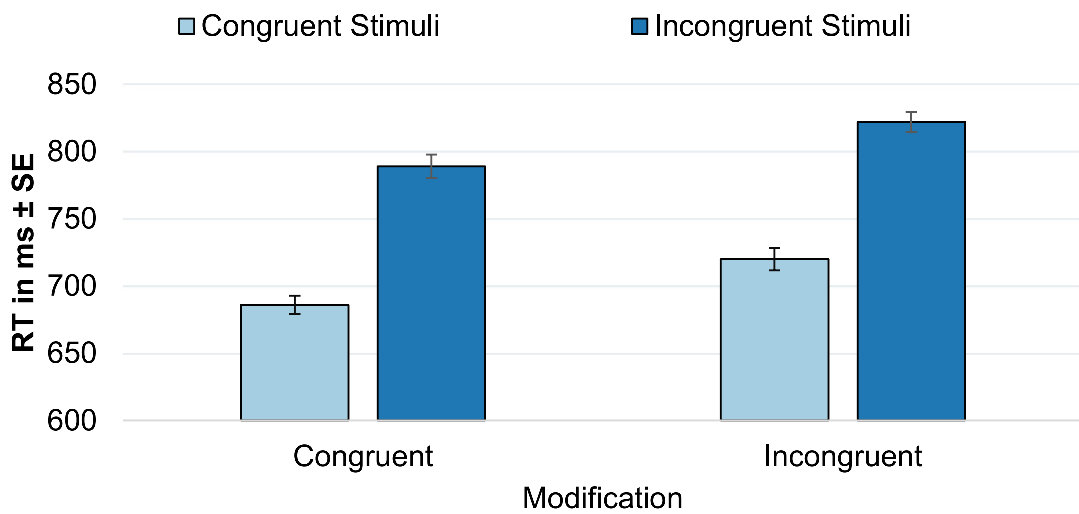

Figure 12. Mean RTs of Experiment 8, separated by stimulus congruency and modification block. Error bars represent standard error of the means (SE)

Errors

Participants committed fewer errors in congruent trials (M = 6.49%, SD = 4.92%, see Figure 13) than in incongruent trials (M = 9.99%, SD = 6.14%, $F(1, 67) = 39.78$, $p < .001$, $\eta_p^2 = .37$). The main effect of *modification* was not significant, $F(1, 67) = 1.08$, $p = .303$, $\eta_p^2 = .02$. Moreover, the interaction of *stimulus congruency* and *modification* was not significant, $F(1,67) = 0.47$, $p = .497$, $\eta_p^2 = .01$.

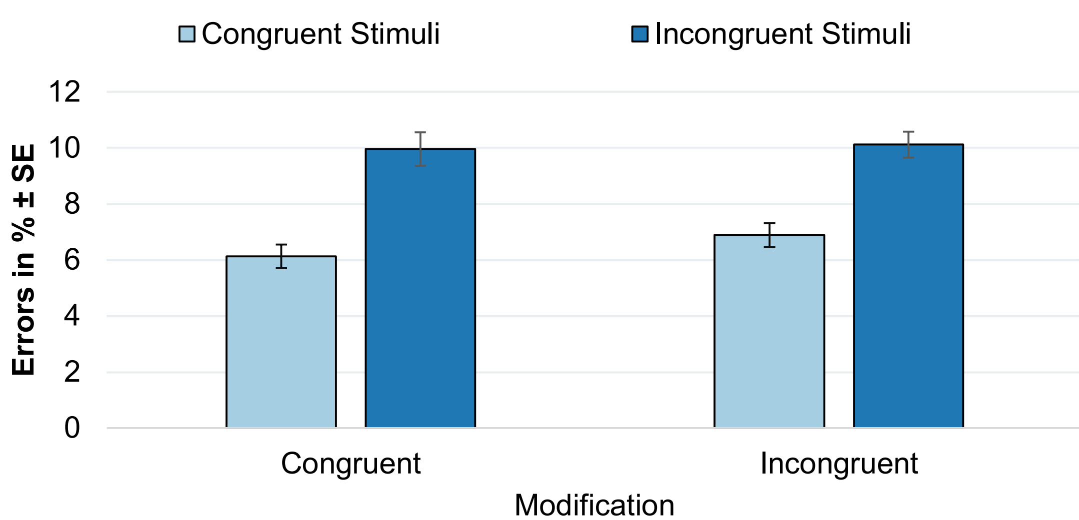

Figure 13. Mean error rate of Experiment 8 separated by stimulus congruency and modification block. Error bars represent standard error of the means (SE)

Discussion

I replicated the finding of Experiment 4 and Experiment 7. People were faster to produce congruent action-products that were predictable in their identity than to produce incongruent action-products of uncertain identity. Crucially, in contrast to the previous experiments, the congruent action-product was not containing the correct answer to the stimulus. People produced action-products in which neither the target dimension of color nor the distractor dimension of word had any overlap with the stimuli they responded to. A facilitation effect by anticipating positive feedback due to the production of an action-product that is connected to the correct response, can not explain the current data. Accordingly, it is unlikely to be the sole reason for the previous results as well. The anticipation of an incongruent situation of unpredictable identity slows down responding compared to the anticipation of a congruent situation of predictable identity. This suggests a role for situation modification in conflict tasks. Despite this, the specific role of affect is unclear so far. In the following, I will describe two experiments in which I measure affect and probe its potential mediating role for situation modification effects in conflict tasks.

5.7 Experiment 9

In the previous experiments, faster response times for the production of congruent and predictable situations might have been caused by the anticipation of positive affect and thus a quicker execution of such an action than an action that is associated with producing an incongruent and unpredictable situation, which is expected to cause negative affect. Although the previous experiments demonstrated that processes similar to situation modification could be at play in conflict tasks, those were based upon several assumptions. First of all, one needs to assume that conflict causes negative affect, and second that negative affect plays a role in how we engage with conflict. There is ample evidence for these assumptions (Dignath et al., 2020), but as I never measured affect, I can not be sure that affect truly played a role in the effects found in the five previous studies. This shortcoming shall be remedied by the following studies in which I used an affect misattribution procedure (Payne et al., 2005) to measure affect in a design otherwise similar to Experiment 4. The hypothesis is that changing incongruent trials towards congruency should lead to relatively positive affect afterward (compared to no change), whereas changing congruent trials to incongruency should lead to relatively negative affect (compared to no change). If this were the case, this would suggest that the response time difference in the modification blocks might be due to affect regulation processes.

The general idea behind the affect misattribution procedure (AMP) is that participants see a task-irrelevant prime and afterward classify a neutral target as positive or negative. If the primes cause any affective change in the participants, this should lead to shifts in the affective evaluation of the target primes. Specifically, primes that cause positive affect should lead a higher probability of judging the subsequent neutral stimulus as positive, whereas primes that cause negative affect should lead to a higher probability of judging the neutral stimulus as negative. If such differences in judgments are observed, inferences about the affective properties of the primes are drawn. I decided to use an affect misattribution paradigm over an affective priming procedure because Fritz and Dreisbach (2013) suggested that the former procedure comes with fewer confounds. They showed that after a priming with incongruent Stroop stimuli, participants were more likely to judge neutral stimuli as negative, than after a priming with congruent stimuli. Furthermore, using Chinese characters (Fritz & Dreisbach, 2013; Experiment 2) led to a larger effect size than neutral German words (Fritz & Dreisbach, 2013; Experiment 1), so I hoped that they would be more sensitive to affective changes caused by conflict.

Methods

To this end, I devised a replication of Experiment 4 with the following changes in the task and the procedure. Participants were instructed to respond to congruent and incongruent Stroop trials in two different modification conditions (congruent vs. incongruent). Additionally, after each Stroop trial, they were presented with a Chinese character for 250 ms, which they had to categorize as positive or negative. They were asked to respond spontaneously and to compare the presented Chinese character to the average Chinese character. Based on the power analysis reported in Experiment 7, I again recruited 60 participants (M_{age} = 24 years, SD_{age} = 6 years, range$_{age}$ = 18 – 57 years), of which 46 identified themselves as female and 14 as male. To create target stimuli for the affect misattribution procedure, I copied a magazine article (Konnikova, 2015) into https://translate.google.de/, translated it to Chinese (traditional), chose all unique characters of which I randomly picked 480 individual characters, which were divided into two lists of 240 each. For half of the participants, the first list was presented in the congruent modification block and the second list in the incongruent modification block, whereas it was reversed for the other half of the participants.

Participants started with a training block of 12 trials to get acquainted with the three-color-word Stroop task (yellow, red, and blue) and the response keys (G, D, and F with their left hand; the key to color mapping counterbalanced across participants). Afterward, they underwent seven trials in which they were asked to classify a Chinese character as relatively positive or negative in comparison to the average Chinese character by pressing K or L on the keyboard with their right hand. Then they completed a congruent modification block and an incongruent modification block in a random order, in which the Stroop task was immediately followed by the affect misattribution task (for the trial procedure, see Figure 14).

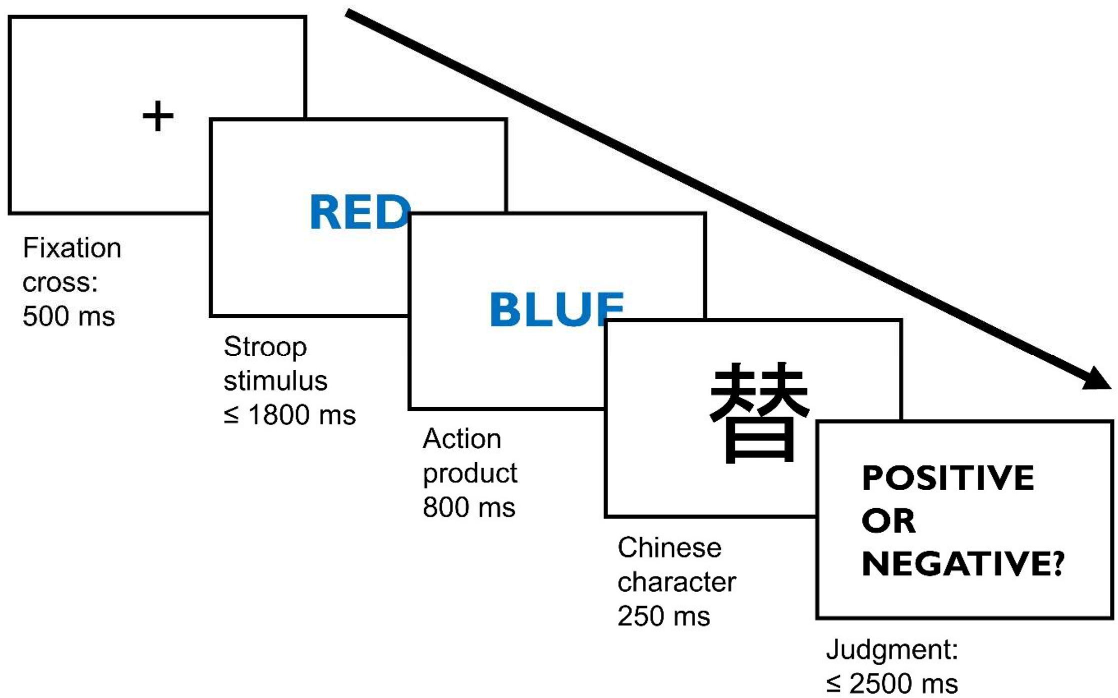

Figure 14. Trial procedure for the congruent modification condition in Experiment 9. If they pressed an incorrect or no key during the stimulus or any key during the action-product, they received an error message for 1500 ms instead of the AMP-task. In the AMP task, they received an error message if they failed to respond in 2500 ms. A blank screen followed every trial for 500 ms.

Results

Data treatment

For the Stroop response times, I excluded error trials (7.6 %) and outliers (1.6 %). As in the previous studies, I excluded the first 64 trials of each block as learning trials. The AMP analysis relied on the same trials as the Stroop RT analysis. For the AMP, I calculated the proportion of cases in which participants judged the displayed Chinese character as more positive than the average Chinese character. I calculated a repeated-measures ANOVA with the factors *stimulus congruency* (congruent vs. incongruent) and *modification* (congruent vs. incongruent) on the Stroop response times, Stroop error rates and the proportion of positive judgments in the AMP.

Stroop response times

Participants responded faster to congruent stimuli (M = 641 ms, SD = 112 ms) than to incongruent stimuli (M = 721 ms, SD = 141 ms, see Figure 15), $F(1, 59) = 158.35$, $p < .001$, $\eta_p^2 = .73$. I replicated the significant main effect of *modification*, $F(1, 59) = 5.86$, $p = .019$, $\eta_p^2 = .09$. RTs were faster in the *congruent modification* block (M = 669 ms, SD = 128 ms) than in the *incongruent modification* block (M = 691 ms, SD = 132 ms). I observed no significant interaction between *stimulus congruency* and *modification*, $F(1, 59) = 0.26$, $p = .610$, $\eta_p^2 < .01$.

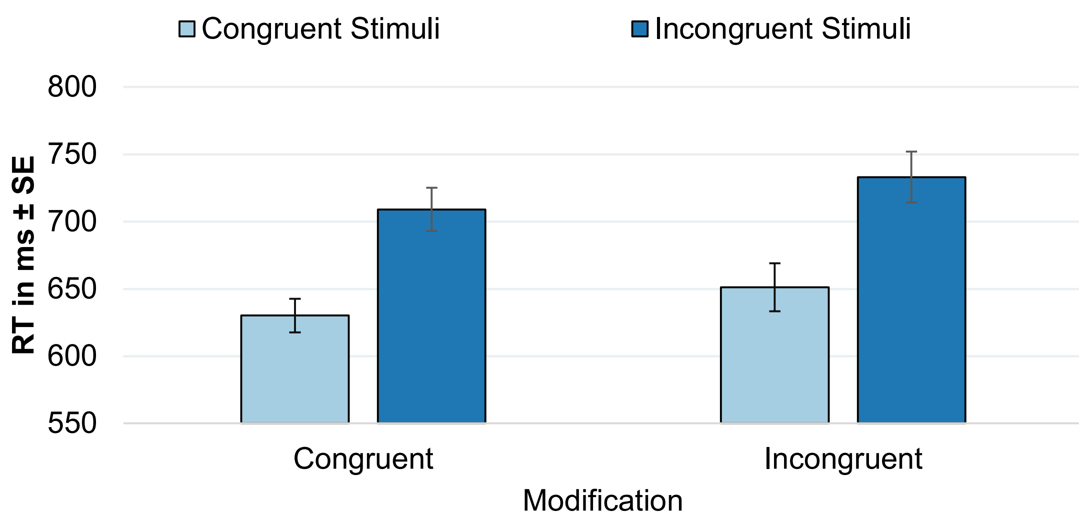

Figure 15. Mean Stroop RTs of Experiment 9 separated by stimulus congruency and modification block. Error bars represent standard error of the mean (SE).

Stroop error rates

Participants committed fewer errors in the congruent Stroop trials (M = 6.37 %, SD = 4.26 %) than in the incongruent Stroop trials (M = 8.84 %, SD = 4.75 %), $F(1, 59) = 23.04$, $p < .001$, $\eta_p^2 = .28$. The error rates did not differ between the modification blocks, $F(1, 59) = 2.86$, $p = .096$, $\eta_p^2 = .05$. Furthermore, there was no interaction between stimulus congruency and modification, $F(1, 59) = 0.66$, $p = .419$, $\eta_p^2 = .01$.

AMP Judgments

There were no significant main effects on the proportion of positive judgments in the AMP, neither of stimulus congruency, $F(1, 59) = 0.15$, $p = .697$, $\eta_p^2 < .01$, nor of modification, $F(1, 59) < 0.01$, $p = .959$, $\eta_p^2 < .01$. Additionally, the interaction was not significant, $F(1, 59) = 1.26$, $p = .266$, $\eta_p^2 = .02$ (see Figure 16).

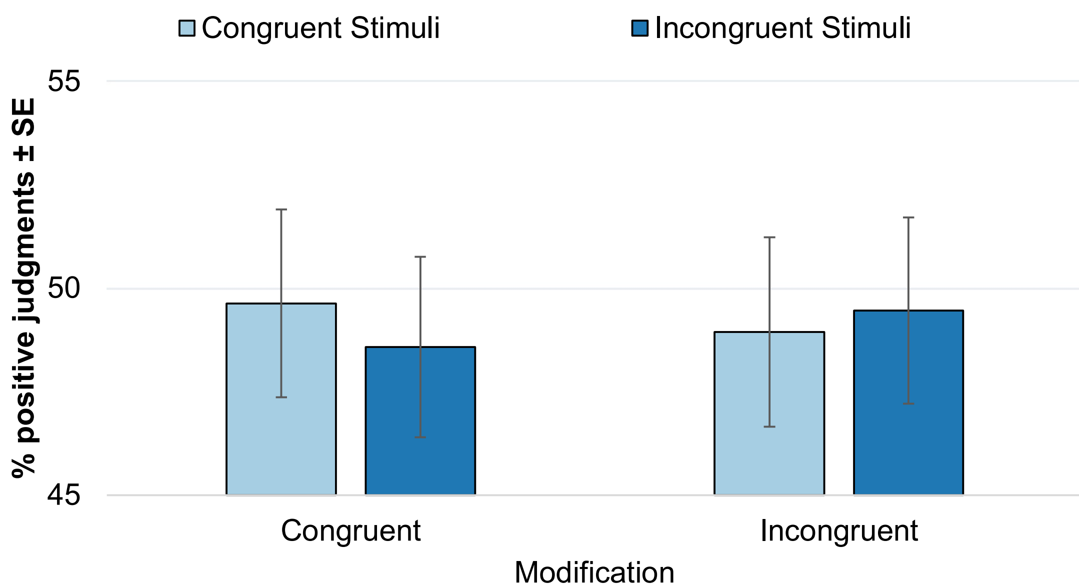

Figure 16. Mean proportion of positive evaluations of Chinese character in Experiment 9 according to stimulus congruency and modification. Error bars denote the standard error of the mean (SE).

Discussion

I replicated the basic finding of a modification effect in a design similar to Experiment 4. Participants were slower when they were forced to create incongruent action-products than when they were forced to create congruent action-products. However, I did not find any evidence for the involvement of affect. There was no evidence that in congruent modification blocks, participants experienced more positive affect after the modification than in incongruent modification blocks. Surprisingly, in addition to that, I did not find any influence of stimulus congruency on the affective priming task. One explanation for that might be that the affect caused by cognitive conflict is rather fleeting and disappeared until participants judged the Chinese character. Given that in previous studies, conflict priming was absent after 800 ms (Fritz & Dreisbach, 2015), the action-product presentation time of 800 ms might have led to a decay of remnants of affect caused by the initial stimulus presentation. Nevertheless, this can not explain the absence of an effect of modification as the action-product immediately preceded the affective priming task.

However, it is possible that the blocked presentation of the modification is not ideal to find differences in the affective priming task. Participants might habituate to the effects of the modification, or they might correctly attribute any affect arising from the modification to the action-product and thus show no change in the evaluation of the Chinese characters. Accordingly, I adjusted the experiment to explore whether there might be any changes in affect due to the presentation of the action-product. To this end, I modified the classical affect misattribution paradigm in a way that it might measure changes in affect over two time-points.

5.8 Experiment 10

To figure out whether the transition of affect due to the resolution or emergence of conflict produced by an action is important, I devised a comparative Affect Misattribution procedure (cAMP). Participants did not compare the presented Chinese character to a typical character and evaluated it as relatively positive or negative, but they compared two characters and chose the more positive one. The difference between those two characters was in their time point of presentation in the trial procedure. One character was presented simultaneously with the stimulus under the assumption that the affect present during the planning and execution of the response would be attributed to this character. The second character succeeded the action-product and thus should be associated with affective states that were active at the end of a trial.

Since there was no residual affective influence of trial congruency and modification detected in the previous study, the succeeding character serves as a baseline, and an increase or decrease in its choice is seen as reflecting relatively increased or decreased affective associations of the simultaneous character. First, if an incongruent stimulus causes negative affect that gets misattributed to the simultaneous character, then the succeeding character should be associated with relatively less negative affect than the simultaneous one and thus be chosen more often as the more positive character. In contrast, if a congruent stimulus causes positive affect that gets misattributed to the simultaneous character, then the succeeding character should be associated with relatively less positive affect and thus be less likely to be chosen as the more positive character. Thus, if the cAMP is sensitive to affect experienced during task-execution, participants should be more likely to choose the succeeding character as the more positive one in the incongruent trials than in congruent trials.

Second, if there is an additional aversive anticipatory affect due to the modification towards an incongruent action-product, participants should be more likely to attribute increased negative affect to the simultaneous character as this is the moment where anticipations should take place. Thus, participants should be more likely to chose the succeeding character as the more positive one in the incongruent modification blocks than in congruent modification blocks. Furthermore, to explore what kind of affect participants experienced consciously during the resolution of the Stroop trials, I asked them to rate positive and negative affect during task execution.

Methods

The experiment closely resembled Experiment 9, except for the following changes. Most importantly, the presentation of the Stroop stimulus was accompanied by the presentation of a Chinese character for 400 ms. Participants responded by pressing A, S, or D with their left hand, which was followed by the presentation of an action-product and a second Chinese character for 400 ms. The judgment task now consisted of these two Chinese characters, presented randomly on either the left and right side of the screen of which participants had to choose the *visually more appealing (positive)* one via button press (K for the character on the left side of the screen or L for the character on the right side of the screen, see Figure 17). Each modification block started with 24 Stroop trials in which they just encountered the action-product without the characters or the judgment task (as in Experiment 7). Subsequently, participants were asked for four of the Stroop stimuli, which action-products they turned into. Afterward, the main experimental block consisted of 120 cAMP trials intermixed with 40 trials in which the judgment task was replaced with a question regarding task-related affect. In these questions, participants encountered an adjective from the German version of the Positive and Negative Affect Scale (PANAS; Krohne, Egloff, Kohlmann, & Tausch, 1996; Watson, Clark, & Tellegen, 1988). They had to rate the extent to which they had this feeling during their response to the Stroop stimulus by pressing a number ranging from 1 (not at all) to 5 (intensely). Half of the 20 possible adjectives were related to positive affect (e.g., alert, attentive), whereas the other half was related to negative affect (e.g., nervous, hostile). Each participant underwent a congruent and incongruent modification block, whose order was counterbalanced across participants.

I planned to recruit 60 participants, based on the power analysis for the *modification* effect. However, due to administrative reasons, I only recruited 58 participants, of which one participant had to be excluded due to an excessive proportion of errors (more than 3 *SDs* from the mean error rate of all participants). Thus, I retained 57 participants for statistical analyses (M_{age} =26, SD_{age} = 6 years, $range_{\text{age}}$ = 20 – 49 years), of which 44 identified themselves as female, the other 14 as male. Fifty-four were right-handed, and the other four were left-handed.

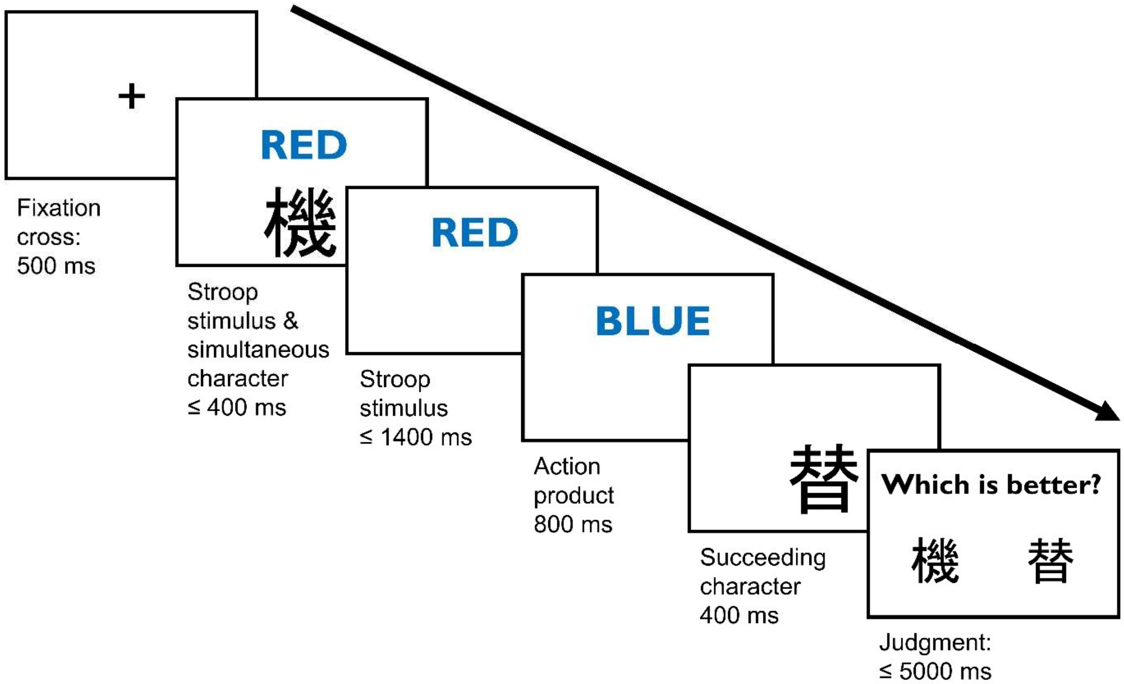

Figure 17. Trial procedure for a cAMP trial in the congruent modification condition in Experiment 10. Every trial was followed by a blank screen for 500 ms. Task-related affect question trials had a similar procedure, except that no Chinese characters were displayed, and the last slide was filled with the question for up to 5000 ms.

Results

Data treatment

As in the previous studies, I excluded error trials (11.4 %) and outliers (1.0 %) for the response times analysis. The initial Stroop practice block was excluded for all of the following analyses. The dependent variable in the cAMP was the proportion of cases in which participants chose the succeeding character. I calculated a repeated-measures ANOVA with the factors *stimulus congruency* (congruent vs. incongruent) and *modification* (congruent vs. incongruent) on the Stroop response times, Stroop error rates, and the cAMP judgments. For the analysis of the mean ratings of the task-related affect questions, I added the factor *affect* (positive vs. negative).

Stroop response times

Response times were lower for congruent stimuli (M = 674 ms, SD = 127 ms) than for incongruent stimuli (M = 746 ms, SD = 134 ms, see Figure 18), $F(1, 56) = 120.93$, $p < .001$,

η_p^2 = .68. Furthermore, I observed a significant main effect of *modification* as participants responded faster *in the congruent modification* block (*M* = 697 ms, *SD* = 132 ms) than in the incongruent *modification* block (*M* = 723 ms, *SD* = 140 ms), $F(1, 56) = 4.72$, $p = .034$, η_p^2 = .08. Additionally, there was an unexpected significant interaction between *stimulus congruency* and *modification*, $F(1, 56) = 5.79$, $p = .019$, $\eta_p^2 < .09$. This interaction was due to a larger congruency effect in the congruent *modification* block, (Δ = 82 ms, *SD* = 62 ms) than in the incongruent *modification* block (Δ = 62 ms, *SD* = 56 ms).

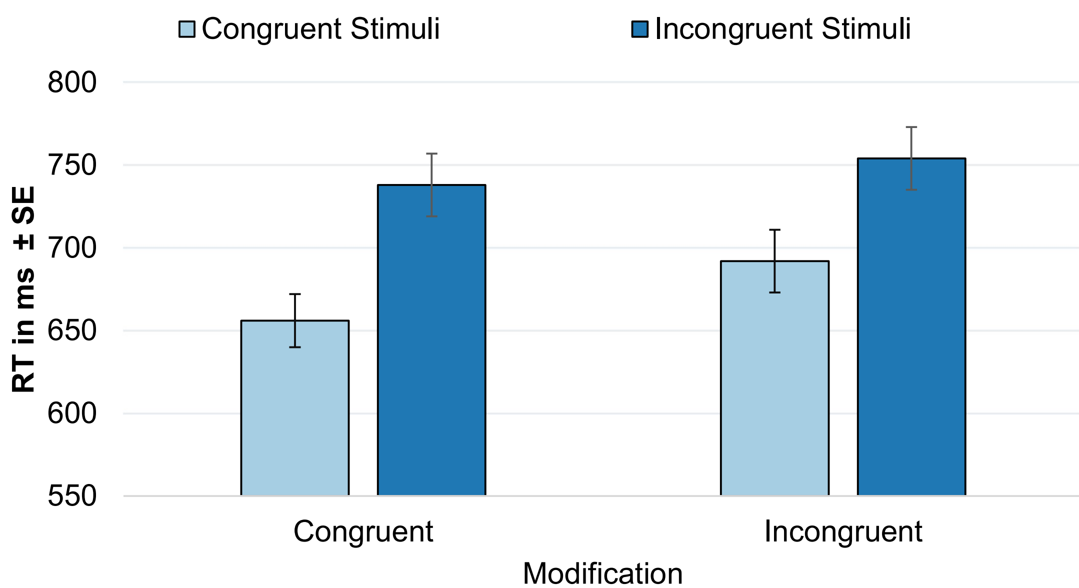

Figure 18. Mean Stroop RTs of Experiment 10 separated by stimulus congruency and modification block. Error bars represent standard error of the mean (SE).

Stroop error rates

A significant main effect of *stimulus congruency* was present, $F(1, 56) = 8.29$, $p = .006$, η_p^2 = .13. Participants made fewer errors for congruent stimuli (*M* = 10.68 %, *SD* = 6.13%) than for incongruent stimuli (*M* = 12.16%, *SD* = 6.48%). Neither the main effect of *modification block,* $F(1, 56) = 0.30$, $p = .586$, η_p^2 = .01, nor the interaction, $F(1, 56) = 0.48$, $p = .493$, η_p^2 = .01, reached significance.

cAMP judgments

Participants were more likely to prefer the succeeding Chinese character over the simultaneous Chinese character in incongruent trials (*M* = 53.54 %, *SD* = 6.55%), than in congruent trials (*M* = 51.38% ms, *SD* = 6.94%, see Figure 19), $F(1, 56) = 6.29$, $p = .015$, $\eta_p^2 = .10$. Their judgments did not differ between the *modification* blocks, $F(1, 56) = 1.02$, $p = .318$, $\eta_p^2 = .02$. Surprisingly, stimulus congruency and modification showed a non-significant tendency towards an interaction in their influence on the cAMP judgments, $F(1, 56) = 3.24$, $p = .077$, $\eta_p^2 = .06$. An exploratory analysis shows, that the difference between congruent (*M* = 51.38%, *SD* = 7.23%) and incongruent trials (*M* = 52.21%, *SD* = 9.73%) is not significant in the congruent *modification* condition, $t(56) = 0.69$, $p = .493$, $d_z = 0.08$, whereas in the incongruent *modification* condition incongruent stimuli (*M* = 54.74% ms, *SD* = 8.11%) led to a higher cAMP judgment than congruent stimuli (*M* = 51.31% ms, *SD* = 9.09%), $t(56) = 3.36$, $p = .001$, $d_z = 0.45$.

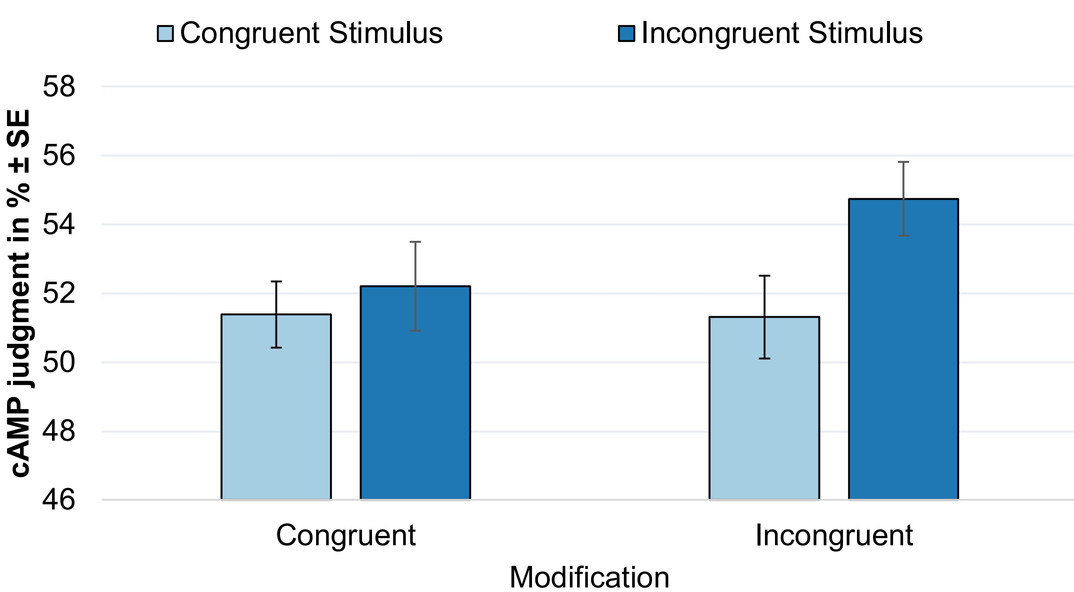

Figure 19. Mean proportion of choice of the succeeding Chinese character in Experiment 10 according to stimulus congruency and modification. Error bars denote the standard error of the mean (SE).

Task-related affect questions

Participants indicated higher values for task-related affect after congruent (*M* = 2.19, *SD* = 0.78), than incongruent trials (*M* = 2.14, *SD* = 0.76, see Figure 20), $F(1, 56) = 4.02$, $p =$

.050, η_p^2 = .07. The main effect of modification was not significant, $F < 1$, but the main effect of affect was significant, $F(1, 56) = 36.70$, $p < .001$, $\eta_p^2 = .40$, due to increased reported intensity for positive affect ($M = 2.44$, $SD = 0.79$), rather than negative affect ($M = 1.89$, $SD = 0.89$). The two-way interaction between stimulus congruency and modification was not significant, $F < 1$, and neither was the interaction of modification and affect, $F(1, 56) = 1.70$, $p = .198$, $\eta_p^2 = .03$, but there was a significant interaction of stimulus congruency and affect, $F(1, 56) = 50.74$, $p < .001$, $\eta_p^2 = .48$. Participants indicated higher values of negative affect for incongruent trials ($M = 1.96$, $SD = 0.89$) than for congruent trials ($M = 1.81$, $SD = 0.91$), $t(56) = 4.79$, $p < .001$, $d_z = 0.63$, whereas they indicated lower values of positive affect for incongruent trials ($M = 2.31$, $SD = 0.77$) than congruent trials ($M = 2.56$, $SD = 0.84$), $t(56) = 5.88$, $p < .001$, $d_z = 0.78$. The three-way interaction of stimulus congruency, modification and affect was not significant, $F < 1$.

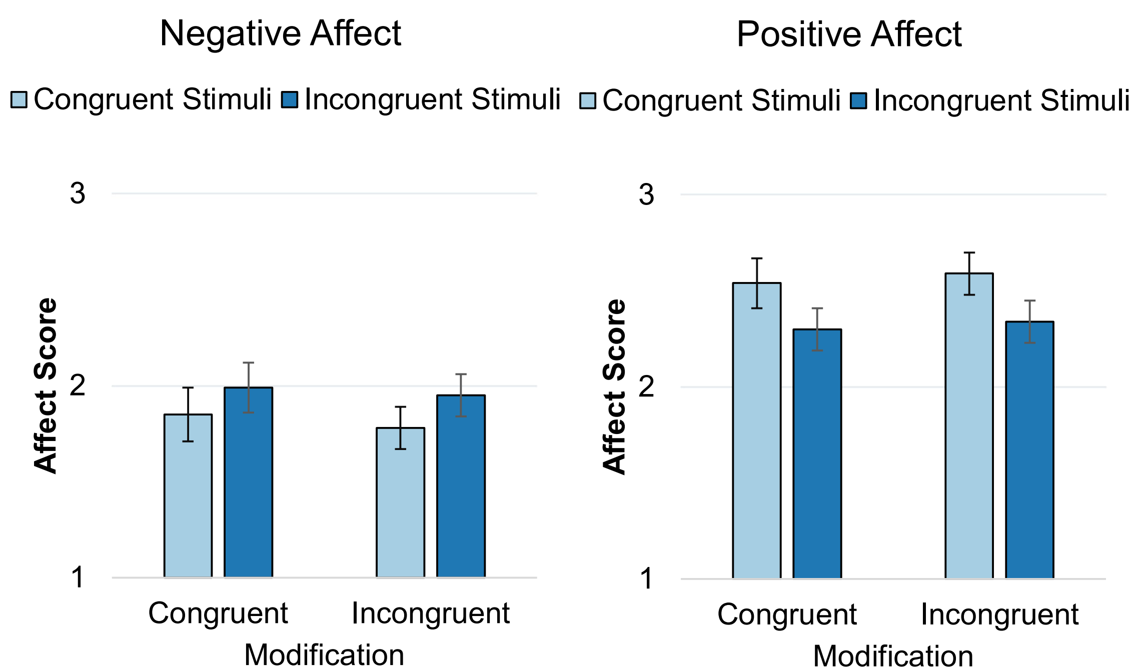

Figure 20. Mean score of task-related affect questions separated by affect valence and plotted as a function of stimulus congruency and modification. Error bars represent standard error of the mean (SE).

Discussion

I again replicated the effect of modification as participants were overall slower in the incongruent modification blocks than in the congruent modification blocks. Unexpectedly, there was a smaller congruency effect in the incongruent modification condition than in the congruent modification condition, similar to Experiment 5. Again, I can only engage in speculations to explain this result. If you look at the means, this interaction seems to be driven primarily by worse performance in congruent trials in the incongruent modification condition, which might be due to a stronger interference by the incongruent action-product in the current study, than facilitation by the congruent action-product for the incongruent trials in the congruent modification block. This may be a small effect that applies to all of the studies in general, but due to power reasons, it only became significant in the current experiment and Experiment 5. As already alluded to in the discussion of Experiment 5, the exposure to a high number of incongruent Stroop stimuli (as the target as well as action-products), may lead to increased proactive control and thus to increased overall shielding off the irrelevant dimension of word content (Hutchison, 2011), thus increasing response times especially in congruent trials.

Nevertheless, this should also lead to smaller response times for incongruent stimuli in the incongruent condition. Furthermore, the interaction could also be the result of a perceptual learning effect, as the repeated exposure to specific stimuli might accelerate their perceptual encoding, which would lead to lower response times for congruent stimuli in congruent modification blocks. However, similar to the predictions of the proactive control explanation, this should also lead to lower response times for incongruent stimuli in the incongruent modification block, which were not observed in the current experiment, despite being observed in Experiment 5.

For the cAMP scores, participants were overall more likely to choose the succeeding character as more positive and, as predicted, they were significantly more likely to do so for incongruent stimuli compared to the congruent stimuli. That appears to support the assumption that in incongruent trials, participants experienced increased negative affect during task execution, resulting in a lowered preference for the simultaneously presented character. Situation modification did not bias participants' judgments in the cAMP by itself but showed a non-significant modulation of the former effect, which tended to be more pronounced in the incongruent than the congruent modification condition. Based on the logic for the comparison of the two Chinese characters, the current result would suggest that participants experienced relatively more negative affect during incongruent trials in the incongruent modification condition than for congruent trials, whereas this was not the case in the congruent modification condition. That could be explained by reduced negative affect in incongruent trials due to the anticipation of the congruent modification. Nevertheless, this interaction was not significant and thus has to be interpreted with caution.

Notably, this interaction would be in line with an affective explanation for the unexpected interaction in the response times. Generally, increased negative affect is associated with increased cognitive control (Dignath et al., 2020). In the incongruent modification condition, the congruency effect is significantly smaller, which speaks for higher cognitive control, and the cAMP effect is non-significantly larger, which might speak for increased negative affect. As I predicted neither of these interaction effects, and the cAMP interaction is not significant, these speculative ideas have to be taken with a grain of salt.

Regarding task-related affect, the primary result is that participants were sensitive to congruent and incongruent trials. They judged incongruent trials as less positive and more negative than congruent trials. That suggests that on an explicit level, there is a perceived difference in valence during responding to Stroop trials, which is in line with other studies using direct measures (Damen et al., 2018). I did not find any effect of modification on these explicit questions, which speaks against the idea that participants experienced increased negative affect during incongruent modification blocks.

5.9 Summary Discussion Situation Modification

Humans tend to change a negative situation to one that is more positive, an emotion-regulating behavior known as situation modification (Gross, 1998a). Assuming that cognitive conflict is aversive, I 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, I found that responses in a classical interference situation, the Stroop task, were generated more quickly when they consistently produced congruent rather than incongruent stimulation (Experiments 4, 7, 8, 9, and 10), even when the action-product showed no dimensional overlap with the imperative stimuli (Experiment 8). However, this modification effect only occurred when the produced stimulation was fully predictable concerning action-product congruency and identity in congruent modifications, but not when the stimulus identity was either perfectly predictable (Experiment 5) or unpredictable (Experiment 6) for congruent as well as incongruent modifications. Besides, I did not find any evidence that this behavioral modification effect is associated with affect (Experiments 9 and 10).

Conflict and certainty

Why did action production benefit only when action consequences were both predictably congruent and of a specific identity? I see several explanations for this. First, humans do not only prefer situations with low rather than high levels of interference (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 et al., 2012). Some influential theories suggest that the brain aims to reduce uncertainty (Friston, 2010), and because of that, certainty is judged more positive than uncertainty, just 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.

Furthermore, it might also be that incongruency that is perfectly predictable in identity can be discounted and, therefore, does not create an anticipatory distraction that may be responsible for the processing deficits. It has been argued that uncertainty about potential aversive experience creates anxiety, which in turn can disrupt cognitive processing (Grupe & Nitschke, 2013). Even though conflict is associated with lower intensity of affect as the stimuli used in these studies, a similar process may take place in the current experiments.

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 the 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.

What does this tell us about affect and conflict?

Against the background of the extended process model of emotion regulation, I hypothesized that people would be inclined towards modifying situations towards the better than towards the worse (Beckers, De Houwer, & Eelen, 2002). The important point here is that the produced action-products contained neither positive nor negative valence explicitly. 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 previous evidence (Dreisbach & Fischer, 2012). However, even though incongruent imperative stimuli were explicitly judged as being more negative than congruent stimuli, the modification of these stimuli did not seem to come with immediate changes of affect, and I could not find any evidence for anticipatory negative affect due to incongruent modification. That 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 in coping 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, and 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 Experiments 5 showed a smaller Stroop effect in the incongruent than the congruent modification condition with overall predictable action products and Experiment 10 showed a smaller Stroop effect for an incongruent and unpredictable modification, Exp. 7 showed reduced Stroop effects for congruent compared to incongruent modifications and for predictable compared to unpredictable modifications. 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 the 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 the conflict was announced in advance (Wühr & Kunde, 2008), even though they could predictably modify the conflicting situation as they could here? Questions like these wait for a closer examination. In the present study, I 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. Even though there was no evidence for the involvement of affect, the regulation of cognitive conflict seems to share commonalities with the regulation of affect.

6 Valuation and conflict adaptation

Up until now, my experiments examined situational emotion regulation strategies, which rely on the selection of affective situations before they occur or the modification of affect-eliciting stimuli when they are already present. These strategies exert influence on behavior when dealing with cognitive conflicts under some circumstances, but I failed to find strong evidence for the involvement of affect. Therefore, I probed the involvement of affect in cognitive control more directly, by testing predictions derived from the application of the extended process model of affect regulation to the adaptation to cognitive conflict. To examine whether sequential modulation of control in conflict tasks could be based on affect regulation processes, I targeted the valuation system as a means to alter the evaluation of conflict. Specifically, the following study tested whether altering the evaluation of conflict-related negative affect produces a shift in conflict adaptation, measured by the congruency sequence effect.

Introduction

Instead of being purely based on cold, cognitive processes, the regulation of cognitive control in conflict tasks may rely on the affective properties of conflict (Saunders et al., 2015). More precisely, the negative affect caused by conflict could be a necessary condition for conflict adaption effects to emerge (Dreisbach & Fischer, 2015). If negative affect triggers conflict adaptation and depends on the appraisal of a situation, changes in the actual or perceived intensity of negative affect should influence adaptation to conflict. That should become evident in a modulation of the congruency sequence effect, which should become smaller with decreased negative evaluations of the prevalent conflict. In previous studies, phasic inductions of affect led to mixed consequences to the congruency sequence effect, but in these cases, affect was mostly induced by task-irrelevant affective stimuli (Dignath et al., 2017; Padmala et al., 2011; van Steenbergen et al., 2009; for a review, see Dignath et al., 2020).

Pessoa (2009) proposed that differences in arousal and task-relevance may explain the diverging results on the influence of affect on performance in control tasks. If arousal is high, the affective significance is likely to distract from control tasks and thus harm performance (Padmala et al., 2011; Schmidts, Foerster, Kleinsorge, & Kunde, 2020). If arousal is low, the influence of affective stimuli on task performance seems to depend on their task-relevance. Low arousing, task-irrelevant affective stimuli are more likely to harm performance, whereas low arousing task-relevant affective stimuli are more likely to enhance performance (Padmala & Pessoa, 2011). That could explain why performance-contingent rewards that create task-relevant affect increase conflict adaptation (Braem, Verguts, Roggeman, & Notebaert, 2012), while rewards not contingent on performance and thus task-irrelevant affect lead to a decrease in conflict adaptation (van Steenbergen et al., 2009).

Absent any affect manipulations, if conflict stimuli inherently carry affective consequences, the negative affect emerges from the task-relevant stimulus and is relatively low in arousal (Zeng et al., 2017). Accordingly, it should enhance performance. If the negative affect associated with the task-relevant stimuli increases, so should the performance. In order to test the predictions of the extended process model of affect regulation (Gross, 2015), I wanted to change the conflict valuation itself, instead of resorting to task-irrelevant affective stimuli.

The evaluation of initially neutral stimuli can change when they get paired with reward (Pavlov, 1928) or other affectively valenced stimuli (De Houwer, 2007). When people learn that conflict stimuli are related to the possibility of positive outcomes (gains), they should perceive them as more positive, whereas learning that conflict stimuli predict negative outcomes (losses) should make their evaluation more negative.

Applying the logic of the valuation system to cognitive control, the association of conflict stimuli with different affective consequences should be able to influence the sequential control of cognitive conflict. If conflict adaptation is one possible affect regulation strategy to deal with the aversive impact of conflict, then an increased negative valuation of conflict should lead to increased effort in the affect regulation action and thus lead to a larger congruency sequence effect when conflict was previously associated with losses. Contrary, if conflict is valuated as less negative, then there should be less need for regulatory actions, resulting in a smaller congruency sequence effect when conflict was previously associated with gains (see Figure 21).

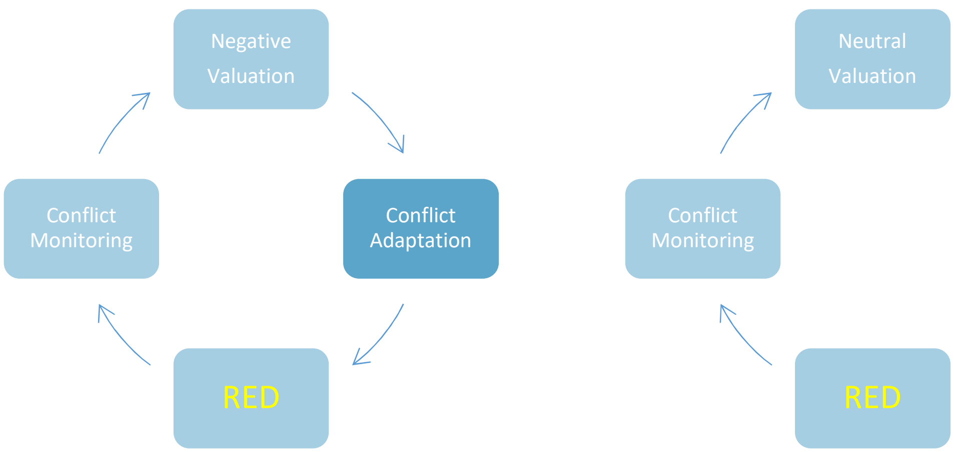

Figure 21. Regulatory cycles when conflict is either associated with a negative valuation (left panel) or with a neutral valuation (right panel). A neutral valuation of cognitive conflict would eliminate the need for regulatory actions.

The pairing of cognitive conflict with reward could possibly also lead to an association of conflict with positive affect. Positive affect has been linked to increased cognitive flexibility and reduced cognitive stability, which comes with higher distractibility (Dreisbach & Goschke, 2004). Applied to the study at hand, increased distractibility would lead to increased congruency effects. Therefore if positive affect leads to higher distractibility, congruency effects should be increased after conflict stimuli that were previously associated with gain compared to those that were associated with loss.

In the current study, I manipulated the affective consequences of conflict stimuli in order to change their valuation and examined whether this influences sequential, reactive control processes. Specifically, conflict stimuli signaled whether gains could be attained or losses had to be prevented in an acquisition phase, to either decrease or increase their association with negative affect. The instrumental reward component was the same amount for gains and losses, whereas the associative component of pleasure and displeasure differed. High task performance led to equal benefits and thus should have had comparable motivational effects on attention and performance. Indeed, previous studies have shown that working to obtain rewards and avoiding loss influences attention in a similar way, given equal incentive value (Engelmann, Damaraju, Padmala, & Pessoa, 2009). However, there have been studies that have shown that gains may be more effective than losses to motivate improved performance in conflict tasks, especially when gains and losses are unbalanced (Carsten, Hoofs, Boehler, & Krebs, 2019). Nevertheless, as gains and losses were balanced in the current study, I expected comparable motivational benefits on performance to occur in the acquisition phase, but diverging affective evaluations of conflict stimuli.

Consequently, I had two nested hypotheses. First, the evaluation of incongruent stimuli should become increasingly negative in the acquisition block of the loss condition, compared to the change of evaluation in the gain condition. Second, if this loss-induced decrease in evaluation occurs, this should influence conflict adaptation. There should be a relative increase in the congruency sequence effect from before to after the acquisition block in the loss condition compared to the gain condition.

Methods

I had no data-based estimate of the size of the difference in conflict adaptation between the conflict-outcome-association manipulations. Therefore I looked up how many participants were needed to find a mid-sized difference (d_z = 0.5) with a power of .95 and an alpha of .05. According to g-power 3.1.9.2 (Faul et al., 2007), 54 participants are needed to achieve such a power. Due to balancing and potential exclusion, I decided to invite 60 participants to take part in the experiment. One participant had to be excluded due to an excessive amount of errors (> 3.5 *SD*s from the mean error rate of all participants), which left 59 participants for analysis (M_{age} = 29 years, SD_{age} = 9 years, $range_{age}$ = 19 – 63 years), of which 16 identified themselves as male (43 as female) and 56 as right-handed (3 left-handed).

To measure conflict adaptation, I used a color-word Stroop task and recorded response times and error rates, captured via keypress on a standard computer keyboard. The experiment file for the study at hand can be found on the Open Science Framework[2] (https://osf.io/6zfkd/). The experiment was divided into two parts with different stimulus and response sets to avoid any carryover between the conflict-outcome-association blocks. Participants solved one of those blocks with the left hand using the keys A, S, D, and F, and the other block with their right hand using the keys H, J, K, and L. The mapping of hand to conflict-outcome-association was counterbalanced across participants. To exclude influences on the congruency sequence effect that stems from sources other than conflict adaptation, specifically effects of partial repetitions and contingency learning (Braem et al., 2019), I chose for each stimulus set four colors, which I split into two sets. That creates full alternations of the stimulus dimension color and word (see also Experiment 3 for this procedure). That means that for the left hand, people switched between stimuli created from red and green (two congruent and two incongruent) and stimuli created from pink and brown (two congruent and two incongruent). For the right hand, they alternated between stimuli created from blue and orange and stimuli created from yellow and gray. That makes sure that there are neither partial repetitions effects due to feature integration, nor any contingency learning features due to unbalanced frequencies of individual stimuli. Participants could not use stimulus features like color or distractor words to detect instances that may signal reward, like in preceding studies examining the impact of reward on

[2] In a pilot study, which was preregistered here: https://osf.io/rhn9e, a programming error occurred. Trials in which congruency alternated (previous incongruent, current congruent; previous congruent, current incongruent) made up the overwhelming amount of trials, leading to a large reverse congruency sequence effect and making any conclusion regarding cognitive control difficult to impossible. Apart from this programming error, the only change to the experiment reported here, are the changes to the stimulus set that control for confounds of feature integration and contingency learning.

cognitive control (Krebs, Boehler, & Woldorff, 2010). Only the detection of conflict signaled gain or loss.

Every trial started with a fixation cross for 250 ms, followed by a Stroop stimulus, which was displayed until a response was given or 2500 ms passed (see Figure 22). If participants did not press a key or if they pressed an incorrect key, they received a respective error message, either "response time window expired" for 3000 ms or "wrong key" for 1000 ms. In the baseline and the test block, a correct response was followed by an inter-trial-interval (ITI), which was a blank screen for 1000 ms, after which the next trial started. In the acquisition blocks, instead of the ITI, they received a feedback display.

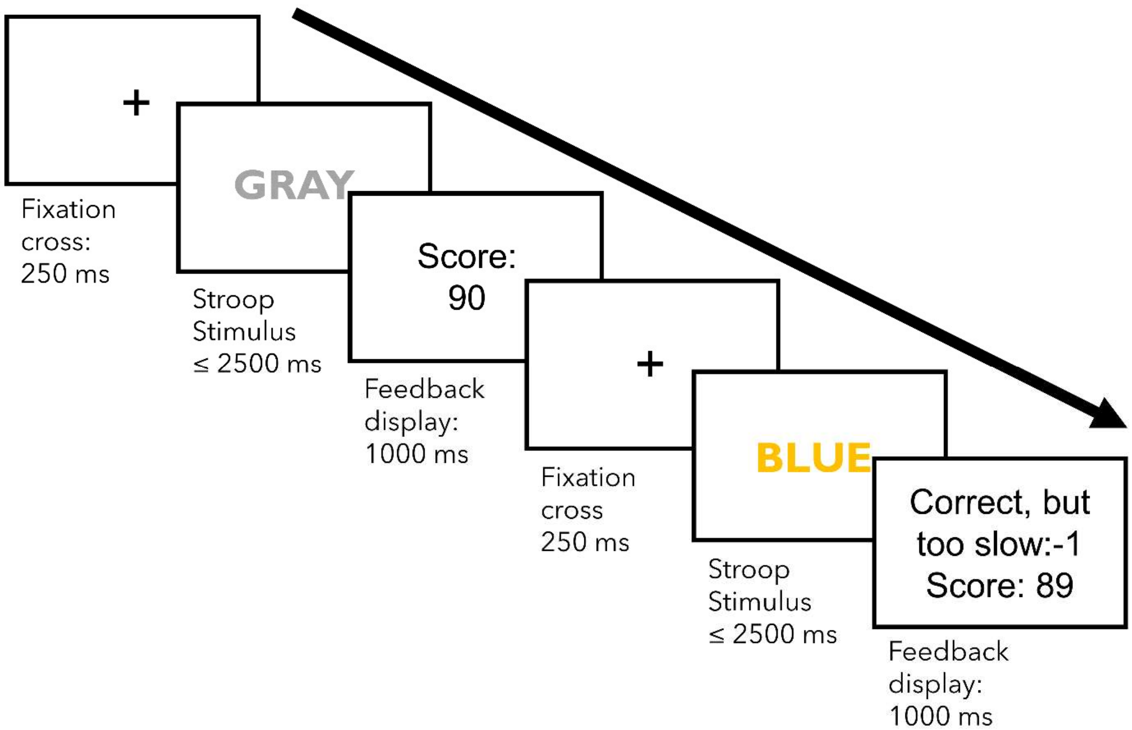

Figure 22. An exemplary trial sequence in an acquisition block of the loss condition in which the participant responded correctly in the congruent trial (the word gray displayed in gray) and in the incongruent trials (the word blue displayed in orange). However, the latter response was slower than the median of all previous incongruent trials from that stimulus and response set, which led to the loss of a point. If the participants had responded faster than the median of these reference trials, then the feedback display would have looked like the one in the preceding trial (i.e., Score: 90). In the gain condition, correct responses in incongruent trials below the median of their reference trials resulted in a display of the current score, whereas response above the median produced "Correct and fast: +1".

For congruent stimuli, this display just showed the current score. For incongruent stimuli, the feedback display depended on the conflict-outcome-association and the response time in relation to the median response time in previous correct incongruent trials with the current stimulus and response set. In both experimental sections, participants started with a baseline block of 80 trials to familiarize themselves with the task and the stimulus-response mapping and to get a baseline measure of the congruency sequence effect (see Figure 23). After that, I measured the valuation of the individual Stroop stimuli by instructing participants to rate their overall impression of the stimuli and to try to feel small differences between them. I displayed the stimulus and asked participants to judge how pleasant they found it on a seven-point Likert-type scale ranging from unpleasant (1) to pleasant (7). I expected participants to judge the incongruent stimuli as less pleasant than the congruent stimuli. Participants then worked on an acquisition block in which conflict stimuli either came with the possibility to gain points or to prevent the loss of points. After that, they again rated the pleasantness of the Stroop stimuli they just responded to. The acquisition block was followed by a test phase without any reward feedback to measure congruency and congruency sequence effects.

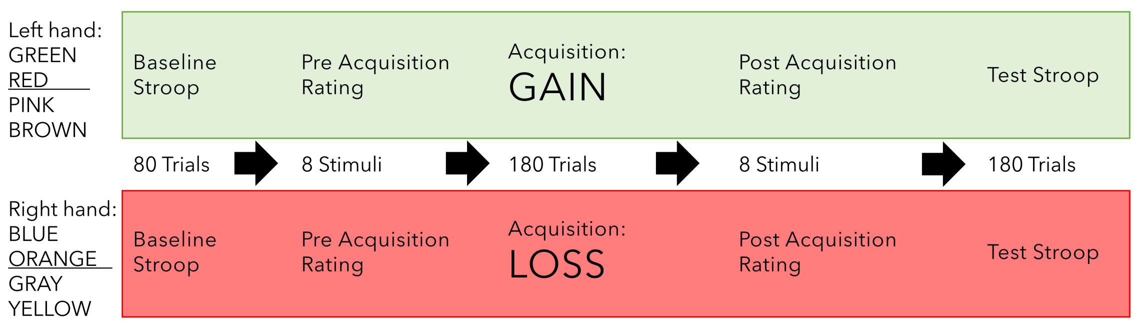

Figure 23. The experiment was divided into two sections. The order of these sections and the assignment of hand / stimulus-response set to conflict-outcome-association was counterbalanced across participants. In both sections, participants started with a baseline block, after which they rated the stimuli, then they did the acquisition block, which was again followed by a stimulus rating. At the end of each section, there was a test block. Subsequently, they started with the other section.

Afterward, participants underwent the same sequence of baseline, pre-rating, acquisition, post-rating, and test block with the new stimulus and response set and the other conflict-outcome-association condition. The order of conflict-outcome-association was counterbalanced across participants. In the acquisition blocks, participants started with a score of 100 points. They were compensated with 9 Euro plus up to 2 Euros depending on the number of points they collected before the end of the experiment (e.g., if they ended with 80 to 100 points, they received one additional Euro, on average participants ended with 10.13 Euros). In the acquisition block of the gain condition, participants obtained a point in all correctly answered conflict trials that were faster than the median response time of the previously correctly answered conflict trials of that block. In the acquisition block of the loss condition, participants lost a point whenever the performance was slower than the median of all trials of that block or if they made an error (otherwise, errors would be the rational response to avoid losses). Participant's reward was measured against the median of their own response time. So even though there was a constant association of behavior and outcome (fast keypress equals better outcome than slow or incorrect keypress), no matter how participants behaved in the gain block, half of the conflict stimuli were associated with a reward. Contrary, in the loss block, half of the conflict stimuli were associated with loss, making the current procedure more similar to simple evaluative conditioning than to operant evaluative conditioning (Eder, Krishna, & van Dessel, 2019).

Since conflict signals potential loss, I expect it to be appraised as more negative in the loss condition, than in the gain condition. In both conditions, the faster half of the trials are positive (gain or no-loss), whereas the slower half (no-gain or loss) are relatively negative. Given that avoidance loss and attainment of gain motivates faster responding and its amount is kept the same in both conditions, I expected similar response times and congruency effects, whereas there should be a change in ratings of conflict stimuli. The ratings for the conflict stimuli should decrease in the loss conditions where they signal potential negative consequences, whereas there should be no such decrease for the gain condition or even an increase in rating. This change in valuation should carry over to the test block, leading to a larger increase of the congruency sequence effect from the baseline block to the test block in the loss condition than in the gain condition.

Results

Stimulus ratings

I calculated a three-way within-subjects analysis of variance with the factors stimulus congruency (congruent vs. incongruent), time (pre vs. post acquisition), and conflict-outcome-association (gain vs. loss) on the pleasantness ratings of the Stroop stimuli. Participants rated congruent stimuli (M = 5.34, SD = 1.29) more pleasantly than incongruent stimuli (M = 3.26, SD = 1.13; see Figure 24), $F(1, 58) = 112.73$, $p < .001$, $\eta_p^2 = .66$. Ratings decreased over time, with higher ratings pre acquistion (M = 4.44, SD = 1.54), than post acqusition (M = 4.16, SD = 1.65), $F(1, 58) = 9.41$, $p = .003$, $\eta_p^2 = .14$. The main effect of time was qualified by a significant interaction with conflict-outcome-association, $F(1, 58) = 5.76$, $p = .020$, $\eta_p^2 = .09$, and a significant three-way interaction, $F(1, 58) = 4.32$, $p = .042$, $\eta_p^2 = .07$. The main effect of conflict-outcome-association, the interaction of congruency and time and the interaction of congruency and conflict-outcome-association, were not significant, Fs < 1.

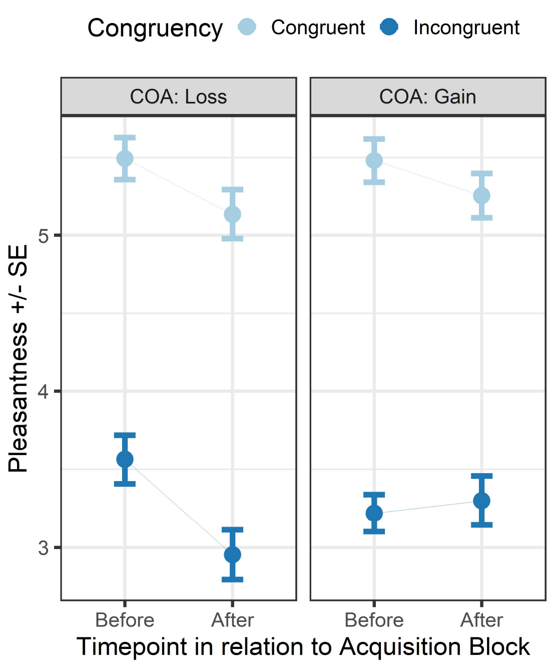

Figure 24. Mean pleasantness rating of the Stroop stimuli separated by conflict-outcome-association, rating timepoint in relation to the acquisition block, and congruency. Error bars denote the standard error of the mean (SE).

To explore the three-way interaction, I calculated two 2 (time) x 2 (conflict-outcome-association) ANOVAs separately for the congruent and the incongruent stimuli. For the congruent stimuli this showed a significant effect of time, due to higher ratings before the acquisition block (M = 5.49, SD = 1.21), than after acquisition (M = 5.19, SD = 1.36), F(1, 58) = 7.49, p = .008, η_p^2 = .11, but no effect of conflict-outcome-association and no interaction Fs < 1. However, for the incongruent stimuli, the main effect of time, F(1, 58) = 4.97, p = .030, η_p^2 = .08, was qualified by a significant interaction with conflict-outcome-association, F(1, 58) = 9.47, p = .003, η_p^2 = .14. To further explore this interaction, I calculated two separate t-tests for the conflict-outcome-association conditions, to probe whether there was a significant influence of time in both conditions. In the loss condition, participants rated the incongruent stimuli significantly lower post acquisition (M = 2.95, SD = 1.22), than pre acquisition (M = 3.56, SD = 1.07), t(58) = 3.53, p = .001, d_z = 0.46. In the gain condition, there was no significant difference for incongruent stimuli according to time, t(58) = -0.52, p = .602, d_z = -0.07. Furthermore, in an exploratory fashion, instead of accounting for the changes in ratings produced by the manipulation, I examined the absolute values of the ratings for incongruent stimuli after the acquisition blocks, and observed that in the loss conditions the ratings were lower (M = 2.95, SD = 1.22) than in the gain condition (M = 3.30, SD = 1.19), t(58) = - 2.00, p = .050, d_z = - 0.26.

Stroop error rates

For the analysis of the error rates, I excluded the first trial of each block and all trials following errors (13.57 %, Danielmeier & Ullsperger, 2011). I calculated a 2 (current congruency: congruent vs. incongruent) x 2 (previous congruency: congruent vs. incongruent) x 2 (conflict-outcome-association: gain vs. loss) x 3 (phase: baseline vs. acquisition vs. test) ANOVA on the error rates. Mauchly's sphericity test revealed a violation of sphericity for the congruency x phase interaction, the conflict-outcome-association x phase interaction, the congruency x previous congruency x phase interaction, and the congruency x previous congruency x conflict-outcome-association x phase interaction, so for these effects, I applied a Greenhouse-Geisser correction.

Participants made less errors in congruent trials (*M* = 10.27%, *SD* = 4.43%) than in incongruent trials, (*M* = 15.49%, *SD* = 5.69%; see Figure 25), $F(1, 58) = 71.42$, $p < .001$, $\eta_p^2 = .55$. Furthermore, there was a significant main effect of phase (Baseline: *M* = 10.69%, *SD* = 6.26%; acquisition: *M* = 16.27%, *SD* = 6.13%; test: *M* = 10.96%, *SD* = 5.15%), $F(2,116) = 23.25$, $p < .001$, $\eta_p^2 = .29$. These main effects were qualified by a significant interaction of congruency and phase, $F(1.66, 96.05) = 18.44$, $p < .001$, $\eta_p^2 = .24$. I calculated the congruency effect (incongruent – congruent error rate) separately for the phases (Baseline: *M* = 5.40%, *SD* = 7.40%, acquistion: *M* = 8.55%, *SD* = 6.62%, test: *M* = 2.15%, *SD* = 4.92%) and compared those in pairwise *t*–test applying a bonferroni correction on the p-values, by taking the observed p-value and multiplying with the number of comparison made (which is mathematically equivalent to adjusting the alpha-level, but keeps the alpha threshold at .05 for all of the following tests). This showed that the congruency effects in all phases differed significantly from the respective other phases, *p*s < .05. The interaction between previous congruency and phase, was not significant, $F(2, 116) = 2.50$, $p = .086$, $\eta_p^2 = .04$. All other main effects and interactions were not significant, *F*s < 1.

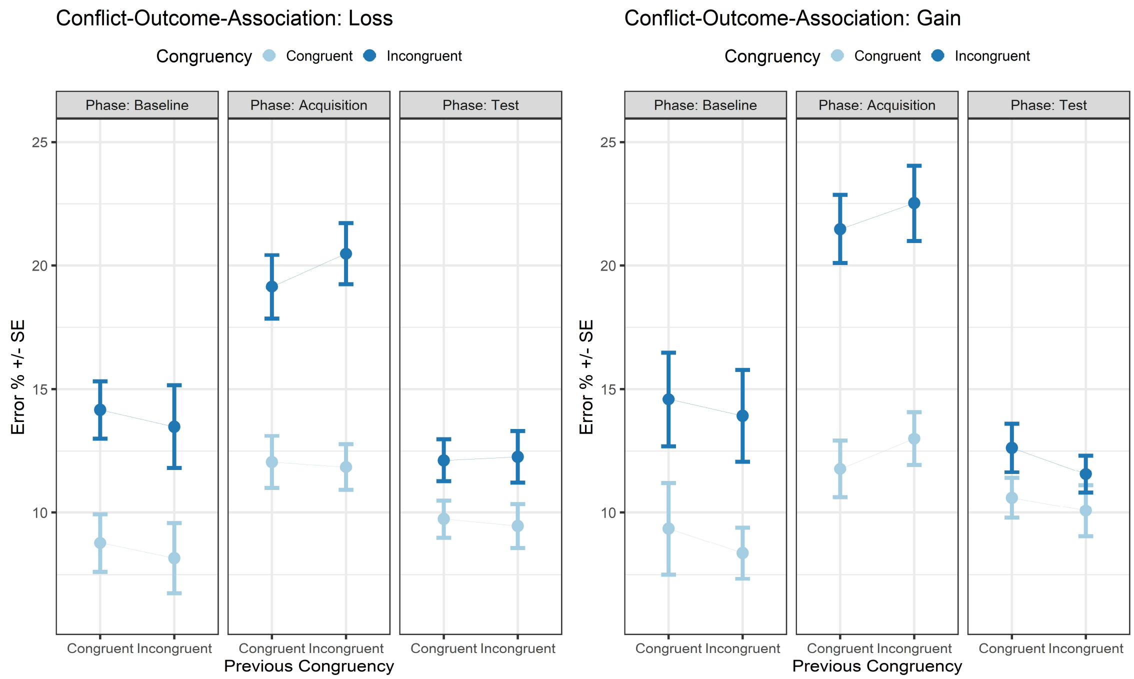

Figure 25 Mean error rates separated by current congruency, previous congruency, phase, and conflict-outcome-association. Error bars represent standard error of the means (SE)

Stroop response times

For the response time analysis I additionally excluded incorrect trials (12.54%), and outliers (response times that deviated more than 2.5 *SD*s from their invidual cell means, 2.98%). For three participants there were empty cells in the baseline block after these exclusion, so they had to be excluded from the following ANOVA. I calculated a 2 (current congruency: congruent vs. incongruent) x 2 (previous congruency: congruent vs. incongruent) x 2 (conflict-outcome-association: gain vs. loss) x 3 (phase: baseline vs. acquisition vs. test) ANOVA on the mean response times. Mauchly's sphericity test revealed a violation of sphericity for the interaction of previous congruency x phase, congruency x previous congruency x phase, previous congruency x conflict-outcome-association x phase and congruency x previous congruency x conflict-outcome-association x phase, so for these effects, a Greenhouse-Geisser correction was used. Participants were slower in response to incongruent stimuli (M = 681 ms, SD = 128 ms) than to congruent stimuli (M = 609 ms, SD = 97 ms; see Figure 26), $F(1, 55) = 141.81$, $p < .001$, $\eta_p^2 = .72$. Furthermore, participants were slower after incongruent (M = 649 ms, SD = 109 ms) trials than after congruent trials

(M = 638 ms, SD = 112 ms), $F(1, 55) = 16.43$, $p < .001$, $\eta_p^2 = .23$. Additionally, there was a significant main effect of phase (Baseline: M = 685 ms, SD = 136 ms; acquisition: M = 614 ms, SD = 123 ms; test: M = 651 ms, SD = 110 ms), $F(2, 110) = 20.39$, $p < .001$, $\eta_p^2 = .27$. Pairwise bonferroni-corrected t–tests showed that all three means differed significantly from the other two respective means, ps < .05. There was a significant two-way interaction of congruency and previous congruency, $F(1, 55) = 5.45$, $p = .023$, $\eta_p^2 = .09$. I calculated the congruency effect separately according to previous congruency. The congruency effect was larger following congruent trials (M = 77 ms, SD = 57 ms), than following incongruent trials (M = 65 ms, SD = 39 ms).

Furthermore, there was a significant interaction of previous congruency and phase, $F(1.79, 98.45) = 22.98$, $p < .001$, $\eta_p^2 = .29$. Follow-up tests revealed that participants were slower after incongruent trials in the acquisition blocks, $t(55) = 10.75$, $p < .001$, $d_z = 1.44$, but not in the test or in the baseline blocks, bonferroni corrected $ps > .69$.

The interaction of conflict-outcome-association and phase was also significant, $F(2, 110) = 6.95$, $p = .001$, $\eta_p^2 = .11$. Follow-up tests revealed that in the gain condition, participants were faster in the acquisition block than in the baseline or test block, Bonferroni adjusted ps < .017, but there was no difference between the baseline and the test block, Bonferroni adjusted p =1. Contrary, in the loss condition, participants were also faster in the acquisition block compared to baseline and test block, Bonferroni adjusted ps < .037, but additionally, participants were faster in the test block, compared to the baseline block, Bonferroni adjusted $p = .002$.

In addition, there was a significant interaction of congruency, conflict-outcome-association and phase, $F(2, 110) = 3.25$, $p = .042$, $\eta_p^2 = .06$. I calculated the congruency effects and analyzed them in two one-way ANOVAs with the factor phase, separately for the conflict-outcome-association conditions. There was no significant effect of phase in the gain condition, $F < 1$, but there was a significant effect in the loss condition, $F(2, 110) = 3.59$, $p = .036$, $\eta_p^2 = .06$. Consequently, I explored this effect in Bonferroni-corrected pairwise t-tests, which revealed that there was a smaller congruency effect in the test condition compared to the baseline condition, $p = .047$.

Most importantly, the predicted four-way interaction of congruency, previous congruency, conflict-outcome-association and phase, was not significant, $F(2, 110) = 0.61$, $p = .526$, $\eta_p^2 = .01$. All other main effects and interactions were not significant, *p*s > .050. Although the results of the four-way ANOVA speaks against an effect, for the sake of completeness, I report the analysis I planned to use to test my hypothesis. For this analysis, I only used the data from the test blocks and calculated a 2 (current congruency: congruent vs. incongruent) x 2 (previous congruency: congruent vs. incongruent) x 2 (conflict-outcome-association: gain vs. loss) ANOVA. The predicted three-way interaction was not significant, $F(1, 55) = 1.04$, $p = .313$, $\eta_p^2 = .02$.

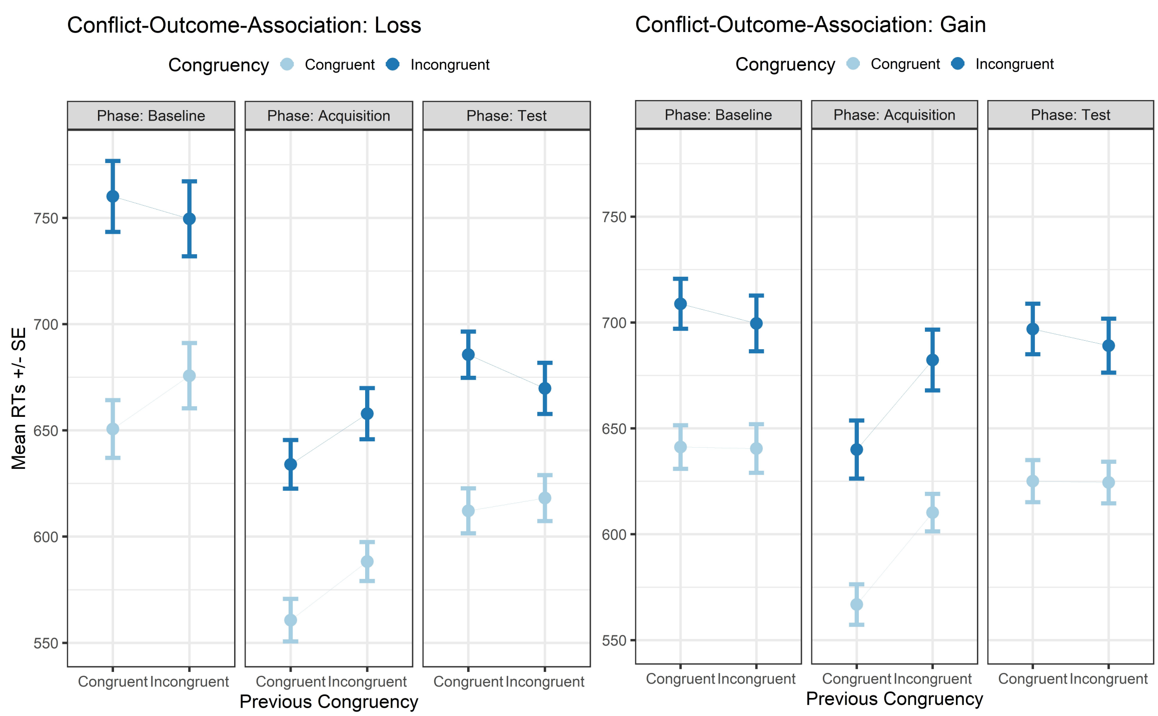

Figure 26. Mean response times separated by current congruency, previous congruency, phase, and conflict-outcome-association. Error bars represent standard error of the means (SE).

Discussion

In this experiment, I examined the potential causal influence of affect on cognitive control by testing whether a change in the evaluation of conflict stimuli impacts the congruency sequence effect. I predicted that associating incongruent stimuli with loss would lead to a decrease in pleasantness, and subsequently to an increase in the congruency sequence effect. While there was evidence for lower pleasantness ratings of conflict in the loss condition compared to the gain condition, I could not detect any evidence for a subsequent modulation of conflict adaption. These results stand in contrast to my predictions derived from the process model of emotion regulation regarding the interaction of affect and cognitive control.

The results of the ratings show that incongruent stimuli were perceived as less pleasant than congruent stimuli, as predicted (see also Damen et al., 2018). More importantly, the conflict-outcome-association manipulation had the desired effect, as participants rating for the conflict stimuli decreased stronger in the loss condition, than in the gain condition, showing diverging affective consequences of the acquisition blocks. While the decrease for the conflict stimuli was significant, there was no significant increase in the evaluation of the conflict stimuli in the gain condition. However, since there was also a general decrease in all ratings (even for the congruent stimuli), the positive effect of the gain acquisition block might just have been enough to counteract that overall decrease. The values for incongruent stimuli after the acquisition block were lower for the loss condition than the gain condition (although the significance test was right at the alpha level of .050), which suggest there was not only a diverging change in conflict-outcome-association but conceivably also an absolute difference in conflict-associated affect between the two conflict-outcome association conditions. Given this difference, if conflict adaptation is based on affect regulation processes, I should have been able to observe a difference in congruency sequence effects in the subsequent test blocks. However, this was not the case.

Even though I controlled for feature integration and contingency learning confounds, there was a significant congruency sequence effect in the response times, which speaks for the occurrence of conflict adaptation[3]. However, the development of this congruency sequence effect throughout a block was not modulated by the conflict-outcome-association. Contrary to my predictions, the congruency sequences effect did not increase to a larger extent from the baseline block to the test block in the loss condition than in the gain condition.

In both acquisition blocks, participants showed a general decrease in response times, which indicates that they were receptive to the incentives. Participants were informed in advance of a block if they could gain or lose points, so they could have upregulated control indiscriminately in the acquisition blocks to maximize payment. However, the decrease in response times in the acquisition blocks came along with increased error rates, which suggests that it merely reflects a shift from a focus on accuracy to a focus on speed and not an improvement of performance.

Surprisingly, in neither of the acquisition blocks, there was a general reduction of the congruency effect, or an enhancement of conflict adaptation, compared to the blocks without incentives. In the error rates, there was even a contrary effect insofar as there were larger congruency effects in the acquisition blocks, which suggest reduced control. However, this could reflect the fact that the feedback leads participants to focus on fast responding (reflected in overall faster response times), leading to the detrimental effects on accuracy. Similar patterns of results have been observed in studies in which people get trial-by-trial cues about rewards in the following trial. In these studies, participants usually show reduced response times, but not always consistent differences in congruency effects (e.g., van den Berg, Krebs, Lorist, & Woldorff, 2014; Veling & Aarts, 2010).

[3] There was no significant congruency sequence in the error rates, but this is not uncommon (e.g., Dignath, Johannsen, Hommel, and Kiesel, 2019).

The influence of reward on cognitive control was not the main focus of the current study, but the absence of an effect of gain or loss on cognitive control in the acquisition blocks is surprising in light of previous studies (e.g., Carsten et al., 2019; Soutschek, Strobach, & Schubert, 2014; Q. Yang & Pourtois, 2018). One possible explanation is that participants concentrated too much on the feedback, leading to reduced attention to the primary task. This explanation would be in line with previous studies showing that aversive feedback in the form of a threat of shock reduced the congruency sequence effect (Jeong & Cho, 2019). Moreover, previous studies with a focus on motivational effects of feedback rewarded congruent as well as incongruent trials (e.g., Q. Yang & Pourtois, 2018), so the specific focus of incongruent trials in my study may have produced a shift in attention that could be detrimental to congruency sequence effects. Stimuli signaling gain or losses capture attention, which in the current case could increase processing of the distractor word and consequently counteract any beneficial influence of reward (Wentura, Müller, & Rothermund, 2014)

Furthermore, the feedback appeared to have a large aftereffect, represented in higher response times and error rates after incongruent trials in the acquisition blocks, which may have overshadowed any measurable changes to adaptation effects in the acquisition blocks. However, as there was no significant interaction between conflict adaptation and phase, the conflict adaption effect does not seem to differ in any of the blocks. Moreover, other studies that failed to find effects of reward on cognitive control explained this by proposing that the reward-control association is mediated by dopamine concentration in the striatum, which I did not control for in this study (Aarts et al., 2014).

The result at hand is hard to reconcile with the view that conflict adaptation is an instance of the regulation of negative affect. If that were the case, increased negative affect should lead to enhanced regulation, resulting in a larger congruency sequence effect. Even though participants rated incongruent stimuli as more negative after they were associated with losses, these rating changes did not lead to changes to the congruency sequence effect. Thus higher negative affect resulting from conflict stimuli is not a sufficient condition for an increase in conflict adaption.

There are several reasons why this might be the case. First, the influence of negative affect on cognitive control could be small, and the current study might lack statistical power to detect this influence. A replication could remedy this power problem with a larger sample size. Second, the association between conflict stimuli and the affect created by the conflict-outcome-association block may be brittle and revert to baseline quickly (extinction learning). Consequently, its strength might be insufficient to influence the congruency sequence effect to a measurable degree over the duration of the test block. To examine this idea, I calculated an exploratory analysis of the test blocks using only the first 100 trials (to keep at least 20 trials in each cell). That did not change the results in direction or significance, so it seems unlikely that there is an initial effect that gradually wears off. Third, conflict adaptation might work implicitly (Blais et al., 2015, but see Desender et al. 2016), and might not be influenced by changes in explicit valuations. People judged the affect of conflict stimuli explicitly and maybe use such information only for explicit regulation strategies like reappraisal and not for conflict adaptation, which might also work implicitly. However, evaluative conditioning is typically relatively robust to extinction and influences implicit measures like affective priming (Vansteenwegen, Francken, Vervliet, Clercq, & Eelen, 2006), so it is not quite clear why affect regulation in the current context should be different.

Finally, negative affect and the regulation of conflict may be relatively independent of each other. Conflict might be associated with negative affect, but this could be unrelated to control processes in any meaningful way (for similar failures to find an association between negative affect and control in the flanker task, see Yamaguchi, Moore, Hendry, & Wolohan, 2020). Given the mixed results of experiments directly testing the influence of phasic negative affect on conflict adaption (Dignath et al., 2020), this can not yet be determined and needs further research.

7 General Discussion

7.1 Summary of findings

In eleven experiments, I examined whether processes that are commonly used to regulate affect can also play a role in regulating responses to cognitive conflict. Derived from the extended process model of emotion regulation, I looked at three different time points in the regulation of conflict. First, I looked at whether situation selection strategies, in which people freely choose to which stimulation they want to expose themselves, can be employed depending on the congruency of the anticipated situation. Second, I investigated whether situation modification strategies are employed to cope with conflict by analyzing whether forcing people to modify situations towards less or more incongruency influences their behavior. Finally, I tested the idea of conflict adaptation as an instance of affect regulation by directly changing the evaluation of conflict, to see whether changes in conflict-related affect are associated with changes in conflict adaptation.

In the first set of experiments, I tested whether the experience of conflict can influence situation selection. People could choose freely between an action that created a congruent situation and an action that created an incongruent situation. In Experiment 1, these actions created a specific congruency with an 80% probability, and participants were not explicitly informed about the contingency between action and subsequent congruency. Participants were not more likely to choose the action that created a congruent situation than the action that created an incongruent situation. In Experiment 2, I increased the contingency between the action and subsequent congruency to 100%. Even so, participants did not prefer congruency-producing actions. That suggests that the experience of incongruency is not enough to induce behavior aimed at reducing such experience of conflict. In contrast, when participants were explicitly informed about the contingency between their actions and subsequent congruency in Experiment 3, they chose the congruent situations more often. That indicates that conflict can trigger explicit affect regulation strategies.

In the next set of experiments, I examined whether situation modification also qualifies as an affect regulation strategy for conflict (Experiments 4 – 10). Participants modified a Stroop task by either changing or keeping the distractor word, thus generating a congruent or incongruent stimulus with their button press. Unless there was no change in congruency, they either had to produce a congruent modification by turning an incongruent situation into a congruent one, or an incongruent modification by turning a congruent situation into an in congruent situation. Experiment 4 showed that participants were faster in blocks in which they produced a congruent modification than in blocks in which they produced an incongruent modification.

However, the congruent modification did not only differ in congruency from the incongruent modification but also in the number of modification stimuli, thus introducing uncertainty as a confound. Indeed, when uncertainty about the identity of the modification stimuli was either reduced in the incongruent modification (Experiment 5) or introduced in the congruent modification condition (Experiment 6), no residual effect of modification could be detected. Owing to this, I tested whether certainty and congruency interact in the production of the modification effects observed in Experiment 4. To this end, I manipulated them independently in Experiment 7 and found that only when the modification was congruent and certain, participants were faster compared to either incongruent or uncertain modifications.

An alternative explanation to situation modification can be construed from the fact that participants only modified the distractor word and not the target color, which means that the resulting modification in congruent and predictable modification blocks was always the correct response. Consequently, the modification effect could have been based on anticipation of the correct response and not anticipation of congruency or certainty. To scrutinize this alternative explanation, I used distinct and non-overlapping stimulus sets for stimuli that people responded to and the modifications they produced (Experiment 8). Participants still were faster to produce congruent and predictable modifications, even when they did not have any relation to the correct response, making the anticipation of feedback as an explanation unlikely.

To test whether the modification effect is associated with affective changes, I combined the task with an affect misattribution procedure but was unable to detect any association with affect, when implicit affect was measured only after the modification (Experiment 9). In a successive experiment (Experiment 10), I probed whether changes in affect can be measured from the timepoint of the response to the Stroop stimulus to after the modification. The results of this new approach of a comparative affect misattribution procedure and explicit task-related affect questions suggest that participants tend to experience increased negative affect in incongruent trials, but do not point towards a consistent effect of modifications on affect.

To figure out whether conflict adaptation, a phenomenon that is construed as a hallmark of cognitive control, might be an instance of affect regulation, I manipulated the affective valuation of conflict stimuli to test whether this manipulation would influence conflict adaptation (Experiment 11). Even though I induced shifts in the affective valuation of conflict stimuli, these did not translate to changes in conflict adaption, suggesting that the affective properties of conflict stimuli may not necessarily be causally involved in cognitive control.

Altogether, the results support the notion that strategies resembling those used to regulate emotions can be deployed to cope with cognitive conflict. However, affect regulation strategies do not translate directly to the domain of cognitive conflict and whether regulation in the latter domain is mediated by affect remains unclear. In the following section, I will describe the inferences that can be drawn from my studies regarding the application of the extended process model of affect regulation to the resolution of cognitive conflict.

7.2 The extended process model and cognitive conflict

Overall, the evidence for an integration of the extended process model of affect regulation with cognitive conflict was mixed. One the one hand, in a narrow sense, I did not find many indications that affect is necessary to control conflict or that strategic influences on the control of conflict are mediated by affect. Nevertheless, in a broader sense, some strategies derived from the process model generate predictions for the control of conflict, which I found to be confirmed by the data. It appears that even if cognitive conflict is not necessarily affective, strategies that are used to regulate emotion can be used to regulate effortful behavior like the resolution of conflict. They might exist in parallel to strategies that are uniquely suited to dealing with conflict like control adaptation.

Whereas in the current experiments, I only looked at one affect regulation strategy at a time, it would be interesting to disentangle the contributions of individual strategies. Presumably, if people can regulate their affect satisfactory with one strategy, they are less likely to engage in other strategies. One could set up an experiment that manipulates whether participants can or cannot engage in situation selection and situation modification. I would predict that the possibility to engage in situation modification should decrease the biases conflicts introduce in situation selection, whereas the possibility for situation modification should decrease the modification effect. Similarly, it would be interesting to explore whether some regulation strategies are preferred over others if multiple strategies could be applied to resolve conflict at the same time. For example, people might prefer to use situation-focused strategies as situation selection or modification over internal regulation strategies as attentional deployment.

The idea of attentional deployment implies a counterintuitive prediction of the application of the extended process model to conflict. Attentional deployment denotes the diversion of attention from the affect eliciting stimuli to reduce its affective impact. In the case of conflict, this is counterintuitive as it would mean that a simple affect regulation strategy would be to reduce conflict monitoring. That would be effective in reducing negative affect produced by conflict, but would probably lead to overall worse performance, especially a higher error rate. Errors are associated with increased negative affect in conflict tasks (Ivanchei et al., 2019), so the strategy of reduction of monitoring may have a net negative effect on experienced affect, which could deter its use. Again, this comes down to the interplay of different affect regulation strategies, and specifically to how their consequences are weighed. Future studies should elucidate which conditions determine the choice of a specific strategy. For example, could the cognitive change of the valuation of cognitive conflict lead to a shift of affect regulation strategy by reducing the downside of attentional deployment to regulate the affective consequences of conflict? In particular, if people successfully downregulate the negative affect triggered by cognitive conflict, could this lead to an increase in an attentional deployment strategy, consequently resulting in decreased conflict monitoring? The test of surprising predictions like this could further evaluate the utility of the extended process model of affect regulation to describe and explain behavior in cognitive control tasks.

Another intriguing question is whether cognitive change can influence control of conflict. There have been indications in previous studies, for example, the finding that the reappraisal of negative pictures can influence subsequent cognitive control. Moser, Most, and Simons (2010) instructed people to maintain, decrease, or increase the emotions they experienced when looking at unpleasant images and measured how this reappraisal influenced a subsequent numerical Stroop task. In blocks in which participants increased their negative emotions, the congruency effect in a subsequent Stroop trial was reduced, compared to a maintenance instruction. Decreasing emotions had no effect on subsequent Stroop trials. These results are in line with the idea that enhanced negative affect benefits cognitive control and show that there can be a lingering effect of reappraisal of unrelated emotional stimuli on cognitive control.

However, the reappraisal stimuli and the Stroop stimuli had no relevant connection, so studies like this cannot inform us whether reappraisal of task-relevant stimuli can be integral to cognitive control. In particular, can people reappraise the aversive value of conflict? Furthermore, if they can, does this influence cognitive control? There are some hints that people might be able to reappraise conflict (N. Cohen, Henik, & Moyal, 2012). Moreover, there is one study by Q. Yang, Notebaert, and Pourtois (2019) that found a negative correlation between the reappraisal scale of the emotion regulation questionnaire (Gross & John, 2003) and the congruency sequence effect. They restricted their analysis to one cell of their experimental design without providing a theoretical reason for the exclusion of three-quarters of trials, so their conclusion has to be regarded as preliminary. Further skepticism arises from the fact that I used this questionnaire exploratively in experiments not reported here and never observed any evidence for a significant correlation of the reappraisal scale and the congruency sequence effect.

Apart from preliminary correlational evidence on an interindividual level, a pilot study I conducted to explore whether reappraisal instruction can influence cognitive control, failed to find an effect on conflict adaptation, and raised several problems. In one study, I told participants to interpret conflict as something positively challenging, and see their successful resolution of conflict as an indicator of their mastery of this task. I wanted to explore whether these instructions change the congruency sequence effect, compared to a baseline condition without appraisal instructions. Specifically, I hypothesized that the appraisal-induced reduction of task-relevant negative affect originating from conflict reduces the congruency sequence effect. Unfortunately, I failed to find a significant congruency sequence effect in either condition, which means that the experiment cannot answer this question. However, in the appraisal condition, I found a general slow-down after incongruent trials, which suggests that participants reappraised incongruent trials to such an extent, that it interfered with the following trials irrespective of their congruency. Introducing reappraisal of conflict might change a simple conflict to a dual-task situation, shifting the attentional focus, which might overshadow conflict adaptation as measured by the congruency sequence effect. The lingering mental load of an additional cognitively demanding task might disrupt sequential adaptations to conflict. High-level reappraisal may thus not be well suited to influence quick and transient reactive control processes.

In contrast to reactive control, it may be more promising to examine if reappraisal of conflicting situations can influence proactive control (Braver, 2012). People could tune their attentional settings before encountering conflicting stimuli and thus change their performance. One approach for future research would be to test whether successful reappraisal of conflict can modify proactive control. The reinterpretation of the affective impact of cognitive conflict could influence measures of proactive control like proportion congruency effects. If people can explicitly downregulate the appraisal of a specific conflict stimulus and if a negative appraisal is necessary for proactive control, then a successful downregulation should decrease the item-specific proportion congruency effects (Braem et al., 2019). If people can generally adopt a mindset that lets them reappraise all conflict stimuli as less aversive and if a negative appraisal is necessary for proactive control, successful reappraisal should decrease the list-wide proportion congruency effect (Gonthier, Braver, & Bugg, 2016).

However, one could also test a different prediction based on the general idea of the regulation model, without a causal role of negative affect in the control of conflict. The conscious experience of conflict as something effortful and aversive may be harmful to its control and performance. The reinterpretation from an aversive obstacle to a most welcome challenging situation could have a positive motivational effect, which enhances control. In this case, its distracting elements might attract less attention, and the exertion of control could be facilitated. Reappraisal of conflict could be a functional strategy that improves control and leads to overall enhanced performance while reducing negative affect. This prediction stands in contrast to the affective-signaling hypothesis (Dignath et al., 2020). On the other hand, it would support the premise that the emotion regulation strategy of cognitive change can contribute to the optimization of behavior in challenging situations.

The possibilities for the application of the extended model of emotion regulation may thus extend beyond affective situations and include regulation of behavior on all levels from higher-order complex emotions like anger to lower-level events like a fast button-press response in a difficult task. It is possible that comparable regulation cycles are pervasive in decisions to apply cognitive effort (Westbrook & Braver, 2015). Cognitive effort might enter a cost-benefit analysis to assess whether the utility of an action is positive. Consequently, the anticipation of cognitive effort might trigger a valuation cycle and could be regulated with strategies like situation selection, modification, and cognitive change.

If that is the case, interesting avenues for future studies would be the application of the extended process model to other areas in which cognitive effort has to be exerted, for example, cognitive flexibility (e.g., task-switching), working memory (e.g., updating), or error processing. Errors can also be construed as conflicts in the sense that the executed response does not match the intended one. It has been shown that errors are aversive (Ivanchei et al., 2019) and that people often try to correct errors immediately after they occur (e.g., Fiehler, Ullsperger, & Cramon, 2005). Error correction might thus be an instance of the modification of an unpleasant situation. In that case, the extended process model would predict that error corrections become more likely with increasing levels of negative affect elicited by the error. That could be tested by inducing affect and measuring the willingness to correct errors after these inductions. For example, one could present negative and positive images before each trial of an error-prone conflict task (Wiswede, Münte, Goschke, & Rüsseler, 2009). A short time window after each response would allow for error-correcting responses. Errors after negative images should be experienced in a more aversive state than errors after positive images and thus trigger an enhanced need for regulation, in this case, situation modification. Consequently, participants should be more likely to correct errors after trials that were preceded by negative images than after trials that were preceded by positive stimuli, even though the error correction does not have any external positive consequences.

7.3 Explicit affect regulation goals and control

One of the crucial differences between the process model of emotion regulation and the understanding of the control of cognitive conflict seems to lie in the explicitness of attaining a desired affective state. The process model of emotion regulation assumes that changing the trajectory of emotions is an explicit goal, whereas, for the cognitive control of conflict, it seems less plausible that changes in affective experiences or attentional focus have the status of an explicit goal. Conflict adaptation effects emerge independently of explicit expectations about the congruency of an upcoming trial (Alpay, Goerke, & Stürmer, 2009). Even though affect regulation can be implicit, absent an affect regulation goal, no regulation occurs (Braunstein et al., 2017). In conflict tasks, people might primarily focus on relevant task goals (responding quickly and correctly) and might not necessarily activate the goal to regulate the negative affect that arises from conflict stimuli. Alternatively, even if this goal is activated implicitly, it might influence behavior only if it rises into consciousness. Support for this idea comes from my studies on situation selection (Experiments 1 – 3), in which participants did not avoid conflicting situations until they were explicitly informed about the contingencies between their actions and the congruency of the subsequent situation. Only when the possibility for the regulation of affect (and effort) was consciously represented, they used it. It is possible that conflict does produce negative affect when people are explicitly asked about it and primes it implicitly for a short time (Fritz & Dreisbach, 2015), but that this affective change does not inevitably enter the conscious experience and thus typically does not trigger affect regulation goals, neither explicitly nor implicitly.

Assuming that the affective consequences of conflict are not necessarily explicit could also explain why the modification effect did not show any connection with affect. Although the way I operationalized situation modification (in a block-wise fashion) did not demand any conscious representation of a modification goal for the participants, because they had no control over the outcome, I expected facilitation through congruent modifications nevertheless because I assumed that the creation of desired situations has a processing advantage. An explanation for the absence of a correlation of modification effects with affective changes may thus be the relatively implicit nature of the modification. It could be that the modification effect does not rely on explicit regulation goals but happens automatically. However, I measured affect not only explicitly (task-related affect questions in Experiment 10), but also implicitly (AMP in Experiment 9 and cAMP in Experiment 10), which did not change the correlation with modification effects. That implies that the modification processes I observed are not related to either implicit or explicit affect, but most likely rely on different mechanisms.

Further evidence for the significance of explicit and implicit processing comes from Experiment 11. I induced explicit changes in the affective valuation of conflict but found no changes in the congruency sequence effect, which speaks against the idea that people consciously engage in conflict adaptation to regulate affective consequences of conflict. The inability of explicit affective experience to influence implicit regulation processes may also explain the high variability in studies examining the link between negative affect and control (Dignath et al., 2020). Possibly, control is only enhanced by an affect signal when there is explicit knowledge that control exertion decreases negative affect. One simple, but confound-prone way to test this, would be to inform participants about the aversive consequences of conflict and that these can be minimized by conflict adaptation, examining whether this knowledge increases conflict adaptation.

Incongruent trials may only be represented as negative when people have the capacity to compare them to congruent trials. That could explain inconsistent affective consequences of conflict. Conflict is reliably associated with negative affect when incongruent stimuli are used as primes (Dreisbach & Fischer, 2012; Pan et al., 2016), but when people respond to conflict, the results are highly variable. In particular, conflict can cause positive affect (Schouppe et al., 2015), it can cause negative affect (Goller et al., 2019), and sometimes it has no consistent effect on affect measures (Ivanchei, Braem, Vermeylen,

& Notebaert, 2020). However, when people have to judge the aversiveness of conflict explicitly, most studies show that it is associated with negative affect, even when people respond to it (see Experiments 10 & 11 of this thesis and Damen et al., 2018).

One of the explanations for the finding that response conflicts show diverging affective consequences is that the resolution of conflict through responding creates positive affect (Schouppe et al., 2015). People build up the expectation that it is harder to solve an incongruent trial, so when they solve it, the positive prediction error is larger than when they solve a congruent trial, which results in increased positive affect. An alternative explanation I suggest here is that conflict is not aversive per se, but only when people are pointed towards a comparison of congruent and incongruent stimuli. These stimuli are similar, except for increased effort associated with incongruent trials. Given that people avoid exerting mental effort that is not related to any kind of benefit (Shenhav et al., 2017), they realize that the experimenter asks them to judge the stimuli according to the only discernable difference. Consequently, when people are explicitly asked to deliver an affective valuation of conflict stimuli or their only task is such a valuation, they are easily able to judge conflict stimuli as more negative than congruent stimuli. However, as soon as they have a primary task to fulfill, for example, responding to the Stroop task, they have less capacity to solve the effortful secondary judgment task, leading to inconsistent results in affect measurements.

This idea could be tested in future studies, for example, by implementing a manipulation of participant's assumptions about the experimenter's demand for the affect measure or by loading their working memory. If these manipulations eliminate the association between conflict and affect, this will provide support for the idea that some of the previous results may have been the product of demand effects or effortful inference processes. Moreover, one could compare whether an affective working memory manipulation (maintaining the emotional intensity of an image in working memory) has a comparable effect on the affective judgments of conflict as a visual working memory task (maintaining the brightness of an image in working memory, Mikels & Reuter-Lorenz, 2019). If loading affective working memory, but not visual working memory, eliminates the conflict affect association, this will provide further support for the idea that conflict is inherently affective.

Furthermore, it has been shown that people introspectively associate incongruent trials with high general activity (Morsella et al., 2009). So they might correctly attribute this activity to the task unless the instructions push them to misinterpret this subjective experience as negative affect. Verbatim instructions given to the participants are rarely publicly available, so this might be an additional explanation for the mixed results on whether the resolution of conflict produces negative or positive affect.

Another explanation for the mixed results on the association of conflict and affect in studies in which people tackle the conflict might be that its implicit affective consequences are relatively small, especially compared to the affective consequences of errors, which cause frustration during task resolution (Ivanchei et al., 2019; Spunt, Lieberman, Cohen, & Eisenberger, 2012). People might also only engage in affect regulation regarding parameters that are under their control (errors) rather than things that are not (occurrence of conflict). For this reason, affect regulation strategies may be more effectively applied to the avoidance of errors than to the adjustment to conflict.

The explicit representations of affect and affect regulation goals are important on all stages of emotion regulation proposed by Gross (2015), namely identification, selection, and implementation. First, the aversiveness of conflict may have to pierce consciousness for people to identify the task as a situation that affords affect regulation. Second, in the selection stage, conflict adaption is just one of many possibilities to deal with conflict, and people might vary in their preferred emotion regulation strategy. Some people may be more prone to situation-focused strategies, whereas others may be more prone to ignoring the affect eliciting stimuli and disengaging from the task. These two strategies would lead to opposite effects on response times, and their selection may depend on whether affect is experienced consciously. Third, even after people selected an affect regulation strategy, the implementation stage may be influenced by whether the aversiveness of conflict is explicitly experienced. It could determine how much cognitive capacity is dedicated to the primary task versus to affect regulation.

One big difference between cognitive control and emotion regulation is that the latter is often a process based on an explicit goal and frequently even an explicit choice of strategy and implementation. Contrary, people probably do not have much explicit insight into how and when they apply cognitive control, for example, by modulating attentional deployment. Many processes that are called cognitive control can happen outside of awareness or are implicit (Kunde, Reuss, & Kiesel, 2012). Accordingly, it is reasonable that explicit emotion regulation processes have a negligible influence on implicit control adaptation. Nevertheless, when conditions for explicit choices were met in the current studies, people did behave in a way that was predicted by emotion regulation.

7.4 Uncertainty

I did not expect uncertainty about upcoming stimulus identity to play a role in regulating behavior. Despite being a serendipitous finding, it is intriguing. Even though I could not find much evidence for the direct role of affect, regulating behavior in response to uncertainty may be an avenue for further research, beyond the application of the extended process model of affect regulation. Uncertainty about the stimuli we interact with permeates our whole life, which means the processes governing this are an area worthy of exploring.

Uncertainty has been examined using the framework of predictive coding (e.g., Clark, 2016). In this view, the mind is a prediction machine and tries to match top-down expectations with incoming sensory input and acts to align predictions with reality (for a critique, see Sun & Firestone, 2020). In the current modification studies, people might have strived to predict congruent situations, leading to interference when they had to produce incongruent situations. Future research should test whether the production of uncertain action-effects is universally impeding compared to the production of certain action-effects. Furthermore, does the production of any uncertain task-irrelevant stimuli influence performance, or do they have to overlap with the task in some way (e.g., by congruency)?

In the modification experiments of this thesis, I manipulated uncertainty about upcoming stimulus identity block-wise. The experiments support the notion of an impact of sustained uncertainty on behavior. However, it is also plausible to assume that transient changes in uncertainty can influence behavior. Previous studies have shown that expectation violations encourage people to switch from selective processing to more explorative processing, leading to the gathering of more information (Chen et al., 2019). In conflict tasks, selective processing is beneficial, so an explorative processing mode induced by outcome uncertainty may produce the observed modification effects. One could test whether the modification effect persists when people are exposed transiently to expectation violations in the congruent modification conditions.

Approaching uncertainty from the perspective of affective regulation also motivates a further exploration of whether and how anticipation of negative affect and uncertainty interact in their influence on cognitive control processes. There has been research on the influence of aversive uncertainty on behavior, specifically, anxiety as a response to unpredictable threats (Robinson, Vytal, Cornwell, & Grillon, 2013). In a study that compared blocks free of shocks to blocks with unpredictable shocks in cognitive control tasks, Y. Yang, Miskovich, and Larson (2018) showed that the anticipation of unpredictable shocks decreased proactive control in the AX-CPT task (in line with the dual competition account; Pessoa, 2008), but increased reactive control measured by the congruency effect in a modified Stroop task. However, in that study, participants could not modify their situation, as there was no contingency between responses and their affective consequences. Uncertainty was thus not related to the identity of the stimulus as in the current experiments, but to the actual appearance of a highly aversive event. A next step would be to figure out more directly whether the uncertainty over the outcomes of an action influences cognitive control in the shock paradigm. Therefore, responses could be paired with shocks of predictable intensity or with shocks of unpredictable intensity. The predictability of the intensity of the shock might reduce aversive anticipation, leading to reduced dual-competition and increased cognitive control, similar to how the predictability of incongruent stimuli decreased the detrimental effect of the modification towards incongruency in Experiment 7.

Uncertainty regarding the perceptual consequences of my actions might influence affect and behavior in myriad ways, and its impact should be explored in future studies. For example, the regulation of uncertainty might be an important part of emotion regulation with the potential even to outweigh the mere valence of a stimulus. Considering the anticipation of shocks again, people could prefer to receive overall stronger shocks of which they know the exact strength compared to situations in which they get shocks of overall lower intensity, but the intensity of a given shock is unpredictable. Moreover, given the influence of uncertainty, anxiety might be a moderating factor for the modification effect. People with anxiety disorders might show a stronger modification effect, whereas people low in anxiety might have a reduced modification effect, thus providing a behavioral measure of uncertainty about future negative states.

7.5 Limitations on generalizability

There are limitations to the generalizability of the current experiments due to my paradigms, constructs, and samples. First, I made statements about cognitive control in general, but I only used one conflict paradigm, the Stroop task. Given that effects related to conflict and affect do not always replicate from one conflict task to another (e.g., Dignath et al., 2017), some of the current findings may be task-specific, and I do not know whether the conclusion transfer to other conflicts or cognitive control as a whole. A pervasive problem in psychology is that universal verbal conclusions are often drawn from rather specific results (Yarkoni, 2019), but it may be especially problematic in the current studies due to the use of a single paradigm. Furthermore, I mainly use congruency sequence effects as a proxy for cognitive control, in which psychometric properties are mostly based on judgments of face validity (as far as I know there are no systematic investigations of construct or content validity for conflict adaptation). For example, given the confounds in early studies on conflict adaptation, it is unclear whether these results can tell us something about cognitive control or whether they reflect task-specific memory processes that provide no generalizable explanation beyond those specific task designs (Schmidt, 2013, 2019). This problem only intensifies as soon as you look for generalizability outside the laboratory (for a deeper discussion, see the following section).

Second, my sample mostly consisted of younger people, many of them students with a high grade point average, which presumably are a very specific population in terms of executive function and cognitive control. The question arises whether mechanisms detected in a group with high abilities generalize to the general population. Furthermore, my samples were made up entirely out of people with a Western, Educated, Industrialized, Rich, and Democratic (WEIRD) background, so it is unclear whether the results can generalized to humans by and large. Although one can assume that processes related to cognitive conflict could be fairly similar across cultures, there are systematic cultural differences in emotion regulation, especially reappraisal and suppression, which could influence generalization (Matsumoto, Yoo, & Nakagawa, 2008).

Another limitation related to my design choices is that in the forced-choice paradigm, people are constricted in their modification possibilities, which is an artificial situation. However, this came with the advantage of measuring performance in comparable conditions. In the real world, people can use avoidance strategies like situation selection, attentional deployment, or suppression more freely than they do in the lab. So a compelling avenue for future research would be to find open paradigms to figure out how people deal with cognitive conflict in their daily life and to what extent they use affect regulation strategies. If they do, the question arises which strategy is the most functional to deal with conflict and to pursue long-term goals and whether this is similar to the regulation of full-blown emotions, in which cognitive change is the most effective (Webb et al., 2012).

The identification of the strategies that are the most instrumental for dealing with cognitive conflict would be the precursor for designing targeted interventions to help people who have problems with cognitive conflicts to regulate them more efficiently. That might create more efficacious cognitive control interventions than those that are currently available. For example, in depression the efficacy of existing cognitive control/working memory training intervention is mixed at best (Koster, Hoorelbeke, Onraedt, Owens, & Derakshan, 2017). Some studies suggest that the influence of cognitive training on emotion regulation might be mostly due to expectations or placebo effects (Long et al., 2020) The resulting interventions could be subclinical, like mindfulness meditation, for which it has been proposed that it enhances emotion regulation by promoting executive control (Teper, Segal, & Inzlicht, 2013). Moreover, similar interventions might also be useful for people with clinical diagnoses as autism, depression or other mental disorders, that are believed to be associated with reduced cognitive control (Grahek, Shenhav, Musslick, Krebs, & Koster, 2019; Solomon, Ozonoff, Cummings, & Carter, 2008). A thorough understanding of the relationship between cognitive control and dysfunctions of human behavior and experience is essential to design suitable interventions.

7.6 Conflict adaptation and real-world behavior

To shine a light on the mechanisms of cognitive control, researchers mainly rely on artificial laboratory experiments. That begs the question of whether those findings generalize to behavior outside of the lab. If the paradigms used in the lab correlate meaningfully with real-world behavior, that would be an indicator that the conclusion gained from these paradigms might have universal value. In the following section, I will give an overview of the predictive value of conflict adaptation measures for other behaviors of interest.

First, cognitive control has to be distinguished from self-control or self-regulation, in which people flexibly adjust behavior in the real world (Inzlicht, Werner, Briskin, & Roberts, 2020). Whereas self-regulation surveys predict real-world outcomes, measures of cognitive control do not, and they also do not correlate with those self-reports (Feldman & Freitas, 2016; Saunders, Milyavskaya, Etz, Randles, & Inzlicht, 2018), suggesting fundamentally different constructs (Eisenberg et al., 2019). Even though the verbal descriptions of these constructs are similar, they seem to work on a different level of analysis, so findings from cognitive control research cannot be generalized to real-world self-regulation and vice versa. Notwithstanding, some broad principles are similar, like control of behavior according to feedback loops that compare the state of the world to a desired goal and monitoring of conflict (Inzlicht et al., 2020). The different levels of analysis may also explain some of the problems in applying emotion regulation principles to cognitive control.

Nevertheless, there are areas for which the cognitive control as the regulation of behavior and attention based on internal goals might be important. For example, substance use disorder is characterized by eleven criteria, four of which refer to *impaired control* (e.g., taking the substance in larger amounts or over a longer period than was originally intended; American Psychiatric Association, 2013). Due to this definitional overlap, there have been arguments for the role of cognitive control in substance abuse. However, the evidence is mostly indirect, for example, by relating assumed functions of neural areas to control and substances abuse (Garavan & Stout, 2005).

If the congruency sequence effect is a valid measure of cognitive control, the data does not support such an association of cognitive control and substance abuse. For example, former methamphetamine users show a general response time slow-down in a flanker task, but no changes in congruency sequence effects compared to controls (Bensmann et al., 2019). That is especially surprising as cognitive control is believed to rely on dopamine (van Schouwenburg, Aarts, & Cools, 2010), and methamphetamine is neurotoxic and causes long-term depletion of striatal dopamine (Carvalho et al., 2012).

However, Methamphetamine users usually show reliable deficits in other tasks that measure executive functions, like the Wisconsin Card Sorting or the Stroop task (Potvin et al., 2018). In other studies, a tendency for heavy drinkers to show increased conflict adaptation was found, which goes against the theoretical prediction of impairment of cognitive control in substance use disorder (J. L. Smith, Mattick, & Sufani, 2015).

People diagnosed with autism spectrum disorder are commonly believed to have problems with cognitive control (Solomon et al., 2008). Nevertheless, the size of behavioral conflict adaption effects does not differ from healthy people, no matter whether the conflict stimuli are non-social (flanker task, Larson, South, Clayson, & Clawson, 2012) or social (emotion face-word Stroop task, Worsham, Gray, Larson, & South, 2015). Moreover, there is no evidence for altered congruency sequence effects in attention deficit hyperactivity disorder, even though the disease is commonly associated with difficulty in behavioral and attentional control (Soutschek et al., 2013).

While there is widespread support for increased congruency effects in patients with major depressive disorder (Snyder, 2013), the results for an association with congruency sequence effects are thoroughly mixed. Some studies found reversed conflict adaptation for people diagnosed with depression (Meiran, Diamond, Toder, & Nemets, 2011). Others found no behavioral difference (Clawson, Clayson, & Larson, 2013; Saunders & Jentzsch, 2014). Furthermore, also an association of depressive symptoms with increased conflict adaptation has been shown (van Steenbergen, Booij, Band, Hommel, & van der Does, 2012).

Similarly, in obsessive-compulsive disorder patients, there is evidence for reversed conflict adaptation (Meiran et al., 2011), as well as increased conflict adaptation (Riesel, Klawohn, Kathmann, & Endrass, 2017), as well as no difference (Hunt, 2017). Resembling this pattern, no clear picture emerges for generalized anxiety disorder, with contradicting evidence regarding associations with conflict adaptation (Gold, Jarcho, Rosen, Pine, & Ernst, 2015; Larson, Clawson, Clayson, & Baldwin, 2013), although there might be an association specifically with adaptation in emotional conflict tasks (Etkin, Prater, Hoeft, Menon, & Schatzberg, 2010).

Furthermore, cognitive control as measured by conflict adaptation does not seem to develop over the lifespan, as 10-year-old children show similar congruency sequence effects as adults (Larson, Clawson, Clayson, & South, 2012) and the same is true for 70-year-old adults (Larson et al., 2016). There also is no development of the congruency sequence effect across adolescence, a period that is assumed to be associated with the maturation of cognitive control capacities (Gyurkovics, Stafford, & Levita, 2020). One exception is a study by Aschenbrenner and Balota (2017). They found that while the congruency sequence effect in the Stroop task increases with age, the congruency sequence effect in the Simon and Flanker task decreases, which raises the questions whether the congruency sequence effects in different conflict tasks are based on comparable attentional control mechanisms and suggests that they might measure different underlying constructs. Even traumatic brain injuries do not seem to have any influence on conflict adaptation (Larson, Farrer, & Clayson, 2011; Larson, Kaufman, & Perlstein, 2009).

A notable exception is Parkinson's disease. People with Parkinson's disease show comparable congruency effects to healthy controls, while congruency sequence effects are eliminated (Rustamov et al., 2013). In that study, there were confounds of feature repetition so that this result could be either due to disturbed conflict adaptation in Parkinson's or due to deficits in short-term memory processes necessary for feature binding effects. Interestingly, the deficits may not be due to Parkinson's disease itself, but due to the medications that are used to treat it, given that as soon as patients are off their medication, their congruency sequence effects are indistinguishable from control participants (Duthoo et al., 2013). Presumably, the dopaminergic medications overdose the brain with dopamine, thus disrupting cognitive control processes.

One reason for the absence of associations of cognitive control tasks and behavior outside the lab might be that the outcomes of these tasks are not particularly reliable. Most studies do not find correlations between different inhibitory control measures (e.g., response time difference scores in Simon and Flanker tasks; Paap & Sawi, 2014). The absence of convergent validity might be due to these tasks being unable to detect inhibitory control reliably or that no such domain-general concept exists as a psychometric construct (Rey-Mermet, Gade, Souza, Bastian, & Oberauer, 2019; Rouder & Haaf, 2019). If each of these tasks only measures task-specific inhibition and control mechanisms, this would mean that findings would not necessarily be generalizable from one conflict tasks to the other and even less to any different variable of interest. Indeed, studies suggest that individual abilities in the congruency sequence effect may be largely task-specific, whereas other behavioral phenomena like post-error slowing may represent a universal psychological construct (Whitehead, Brewer, & Blais, 2019). Consequently, disruptions of error processing are associated with mental disorders like schizophrenia (Boudewyn & Carter, 2018), whereas despite sound theoretical predictions, no deviations of conflict adaptation are found in schizophrenic patients (Abrahamse et al., 2016; Abrahamse et al., 2017).

Braem et al. (2019) argue that the absence of a correlation of the congruency sequence effect with constructs related to cognitive control or real-world variable may be due to a general ineptitude of tasks that produce reliable within-subjects differences to be used as a between-subjects measure (Hedge, Powell, & Sumner, 2018). This ineptitude should apply to congruency effects in the same way, but those do sometimes correlate with real-world variables (e. g., Lansbergen, Kenemans, & van Engeland, 2007; Snyder, 2013). That calls into question whether congruency sequence effects are related to a construct of "cognitive control" in any meaningful way. Most of the previously reviewed studies relating the congruency sequence effect to other variables did not control for low-level learning confounds, most notably feature binding and contingency learning processes (Schmidt, 2013). If most of the variation in congruency sequence scores comes from contingency learning and feature binding processes, it is not surprising that there is neither much overlap between these tasks, nor any relation to real-world variables linked to cognitive control. It might be the case that many studies that stated to investigate conflict adaptation and the control of conflict, actually examined different processes, not at all related to the construct of control or executive functions. That makes the previous literature on the congruency sequence effect hard to interpret.

An additional explanation for the absence of an association between cognitive control as measured by the congruency sequence effect and real-world self-control outcomes may lie in the idea that inhibition and its control are not that important for self-control. Buckholtz (2015) argues that the importance of response inhibition as it is measured in the lab is overrated for the control of actual behavior, which is mainly based on value-based decision making and thus much more determined by the values of action depending on the predictions of future outcomes. Accordingly, response inhibition and its cognitive control still play a role, but its role may consist of the interaction with the valuation process. If that were the case, it is not surprising that the performance in a simple lab task may not be able to predict actual behavior that is associated with strong valuation cycles. That adds to the weight that has to be given to finely entangle the interplay of cognitive control and affect regulation processes, with an eye to the valuation of specific actions. More generally, can emotion and cognition be meaningfully separated? Or are they intertwined at any level of processing? It has been suggested that the dichotomy of emotion and cognition is artificial and cannot be held up in light of increasing knowledge about the underlying psychological processes and neural systems (Okon-Singer, Hendler, Pessoa, & Shackman, 2015).

In the early days of academic psychology, a great deal of attention was paid to the study of emotion (James, 1884). However, this initial euphoria disappeared with the emergence of research traditions that downplayed the relevance of affective processes, either in favor of behavior (Skinner, 1965) or in favor of cold cognitive computational processes (the mind as a computer, e.g., Newell, Shaw, & Simon, 1958). In recent years this has been remedied by a resurgence of research on the role of emotion, which revealed that affective processes do not exist incidentally in a separate module but that they influence both behavior and cognition in a wide variety of situations (Fox et al., 2018). That indicates that the regulation of affective processes also intersects with the control of actions and thoughts.

7.7 Concluding remarks

Previously held ideas about separation of emotion and cognition in processing or underlying neural architecture increasingly crumble under scrutiny. The work in this dissertation adds to the existing literature on the interaction between cognitive control and affective processes by focusing on processes derived from emotion regulation frameworks. Strategies commonly employed in emotion regulation like situation selection can be used to engage with cognitive conflict. Regulation of affect and control of behavior in conflict tasks can be based on comparable processes, like situation modification. These strategies and processes can even be applied in the absence of affective changes. My research contributes to a better understanding of the affective regulation of cognitive conflict, and I hope that it can stimulate future research to shed light on how emotion and cognition interact to guide human experience and behavior throughout our life.

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