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ORIGINAL ARTICLE

Reappraising cognitive control: normal reactive adjustments following conflict processing are abolished by proactive emotion regulation

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Abstract

The congruency sequence effect (CSE) reflected by the influence of the congruency of the previous trial on the current one translates improved cognitive control (CC). Yet, it remains debated whether reactive or proactive control processes mostly contribute to this effect. To address this question, we administered a Stroop task controlling for effects of feature repetition and contingency learning to a large group of participants, where we manipulated the frequency of incongruent trials in a block-wise fashion to induce either proactive (high-conflict frequency) or reactive (low-conflict frequency) control. Moreover, as the presentation of trial-by-trial evaluative feedback could influence control processes operating at a local level, we compared effect of evaluative vs. neutral feedback on the CSE, for each control mode separately. We tested the prediction that CSE should be influenced by conflict frequency and feedback type concurrently. Results showed that when evaluative feedback was used, the CSE was increased if conflict frequency was low, confirming that the CSE stemmed from reactive control mainly. If conflict frequency was high, a different sequence effect was observed. The use of neutral feedback abolished the modulation of the CSE by conflict frequency. Moreover, correlation results showed that reappraisal, corresponding to a proactive emotion regulation strategy, was negatively related to the CSE in this condition, suggesting that proactive control can alleviate the reactive dominance of the CSE. Altogether, these results suggest that CC is flexible, and its expression depends on the subtle balance between proactive and reactive control processes.

Introduction

Cognitive control (CC) is a fundamental ability that helps people to flexibly adjust attention and decision-making according to current goals, particularly when overcoming prepotent or habitual responses (Alexander & Brown, 2010; Shenhav, Cohen, & Botvinick, 2016). This ability is fairly complex and assisted by different processes that can be dissociated from one another. According to the dual mechanisms of control (DMC) framework, CC is not unitary but two distinct control modes can be identified, namely reactive and proactive control (Braver, Gray, & Burgess, 2007, Braver, 2012). Upon the detection of interference, especially if it is unexpected and/or of large magnitude, reactive control is used to reduce or resolve it, corresponding in turn to a 'late correction' mechanism (Braver, 2012). However, in some situations, the encounter of interference can also be anticipated and specific preparatory or sustained control processes changed accordingly. In this case, proactive control is used and it can be conceptualized as an 'early selection' mechanism (Geng, 2014; Braver et al., 2007).

Using interference paradigms (i.e., Stroop task, Flanker task, or Simon task), it is generally assumed that the magnitude of the congruency effect (CE) can be regarded as a signature of proactive control mode, in which higher CE translates impaired proactive control (Funes, Lupianez, & Humphreys, 2010). In comparison, the modulation of the previous congruency on the current ones, which is called the congruency sequence effect (CSE), is usually explained by

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conflict adaptation where reactive control operates dynamically at a local, trial-by-trial level (Notebaert & Verguts, 2008; Egner, Ely, & Grinband, 2010; Alpay, Goerke, & Stürmer, 2009; Botvinick, Braver, Barch, Carter, & Cohen, 2001). CC is adaptive and flexible in the sense that the involvement of reactive and proactive control processes actually depends upon specific factors that can be external or internal, and manipulated at the experimental level. For instance, previous studies clearly showed that CC can be geared towards proactive control when the frequency of incongruent trials within the block is transiently increased (Bugg, 2012; Gonthier, Braver, & Bugg, 2016), the duration or gap between two consecutive trials is increased (Egner et al., 2010), or specific cues informing about the nature of the upcoming trial type are used (Aarts, Roelofs, & Van Turennout, 2008). Hence, the amount of reactive and proactive control used to deal with interference likely varies depending on specific factors (Torres-Quesada, Funes, & Lupianez, 2013; Funes et al., 2010). Further, the variability in CC seen across trials and subjects, as well as tasks or contexts, can probably be accounted for in part by variable transition effects from one dominant control mode to the other one (Braver, Paxton, Locke, & Barch, 2009; Paxton, Barch, Racine, & Braver, 2008).

As mentioned here above, the CSE is usually regarded as the expression of a transient control mechanism, being primarily reactive (Egner et al., 2010; Alpay, Goerke & Sturmer, 2009). This interpretation is also in line with the dominant conflict-monitoring theory (Botvinick et al., 2001). However, the fact that the CSE is mostly conceived as a form of reactive control does not invalidate the notion that it can also be influenced by concurrent control processes that are mostly proactive in essence. For example, a typical CSE was previously reported in situations where proactive control presumably dominated, because of the use of a larger frequency of incongruent trials within the block (Soutschek, Strobach, & Schubert, 2014; Torres-Quesada et al., 2013), or the presentation of a cue informing about the imminent occurrence of conflict (Correa, Rao, & Nobre, 2009).

Further, it has even been proposed that the more efficient conflict processing usually observed after incongruent trials compared with congruent ones might actually reflect in part the proactive preparation occurring from one trial onto the next one (Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Hinault, Badier, Baillet, & Lemaire, 2017). Therefore, proactive control likely modulates conflict-driven adaptive control, in the sense that it is probably shaped by specific preparatory processes which are based on specific expectations (Gratton, Coles, & Donchin, 1992), or through activating processes that anticipate conflict and are meant to reduce interference (Burgess, & Braver, 2010), or perhaps its negative or aversive nature (Dreisbach & Fischer, 2012). As put forward recently, it is plausible that the CSE corresponds to a reactively triggered control mode that leads to short-term increase in proactive control (Duthoo & Notebaert, 2012; Scherbaum, Fischer, Dshemuchadse, & Goschke, 2011; Appelbaum, Boehler, Davis, Won, & Woldorff, 2014). In this framework, the variable and concurrent involvement of these two control mechanisms within the same trial provides a rather efficient way to overcome the limitations imposed with the use of proactive or reactive control exclusively, with the former being resources consuming and the latter associated with lower or slower performance (Karayanidis et al., 2009). Thus, it appears parsimonious to regard the CSE as a blend of reactive and proactive cognitive control processes, implying in turn that CC operates at different levels and perhaps different scales, either globally and before the conflict arose in the case of proactive control, or instead locally and after it, in the case of reactive control (Braver, Paxton, Locke, & Barch, 2009; Bugg, 2012; Suzuki & Shinoda, 2015; Rigoni, Braem, Pourtois, & Brass, 2016).

The main goal of the current study was to assess whether proactive or reactive control mechanisms underpinned the CSE. More specifically, we assessed whether systematic variations in the relative contribution of proactive vs. reactive control processes could modulate its expression and magnitude. To this end, we altered the frequency of incongruent trials in a block-wise fashion, a standard method that has been used in previous studies (Funes et al., 2010; Soutschek et al., 2014; Grützmann, Riesel, Klawohn, Kathmann, & Endrass, 2014). Specifically, we induced proactive control by increasing the frequency of incongruent trials to 70% in specific blocks. In different blocks, this frequency was set to 50% (meaning a balanced number of congruent and incongruent trials) and hence, as a result, the use of reactive control mode was promoted therein.

Crucially, we then assessed, in a factorial design, how this specific variable (i.e., conflict frequency) could interact with another one namely, the type of performance feedback used. The presentation of evaluative feedback at the single trial level could be used as a means to influence control processes operating at a local level, and hence the balance between proactive and reactive control (Braver, 2012; Locke, Braver, 2008). Based on the evidence reviewed here above, we reasoned that evaluative feedback should have different impacts on the CSE depending on conflict frequency. More specifically, evaluative feedback (with a higher motivational significance) should strengthen reactive control when conflict frequency is low, thereby increasing the CSE (see also Van Steenbergen, Band, & Hommel, 2009, 2012; Yang & Pourtois, 2018). By comparison, this increase in the size of the CSE should not be observed when conflict frequency is high and thus proactive control presumably dominates. Further, we hypothesized that neutral feedback, which is devoid of any specific motivational significance, should not influence the CSE depending on conflict frequency (see Yang

& Pourtois, 2018). To test this prediction, we therefore, manipulated the type of feedback presented at the single trial level across different blocks. After each response, a single feedback was always presented after a fixed 700 ms interval, hence it was always contingent on this event. However, in half of the blocks, this feedback was evaluative since it provided information about actual task performance (accuracy and speed). Hence, either a positive or negative feedback was presented depending on actual performance. In the other half, the feedback was always neutral (for a similar manipulation, see Yang & Pourtois, 2018).

Additionally, we also measured negative affect (as a state) and its regulation (as a trait). It was found previously that conflict is inherently aversive and thus negatively connoted (Dreisbach & Fischer, 2012). Recently, we also found that the CSE was increased during the encounter of integral negative emotion (Yang & Pourtois, 2018). Negative emotion might provide another source triggering enhanced control adjustments, given the close ties between defensive motivation and CC (Inzlicht, Bartholow, Hirsh, 2015). From this affective perspective, it is reasonable to conceive that conflict-driven adaptive control processes could be regarded as a form of emotion regulation to some extent (Dignath & Eder, 2015; Dreisbach & Fischer, 2015). According to a dominant model in the affective sciences literature (Gross, 2002), emotion regulation can be divided into different processes or strategies, including suppression and cognitive reappraisal. Suppression corresponds to the inhibition or downplaying of emotional reactions, once they are elicited, and is usually conceived as mostly reactive. In comparison, reappraisal entails changing the meaning of emotional event or reaction, either proactively or reactively. Using this framework, we therefore, sought to assess in this study whether these two different emotion regulation strategies, when conceived as dispositions, might correlate with CC and more specifically the CSE. To this end, we adopted an inter-individual approach and performed correlation analyses between the ERQ (Gross & John, 2003), state negative affect (using the PANAS, see Watson, Clark, & Tellegen, 1988) and the CSE, as extracted from the main interference task used in this study.

Method

Participants

Initially, 60 participants were included and 6 of them were excluded from the analyses because of a mean accuracy lower than 70%, precluding in turn to obtain enough trials for some conditions (such as congruent–Congruent, incongruent-Congruent, or congruent-Incongruent) when high-conflict frequency was considered (i.e., 70% incongruent trials). They were compensated with 1 course credit. However, a subsequent power analysis, using MorePower (Campbell & Thompson, 2012) and our previous study as prior (Yang & Pourtois, 2018), showed that 70 participants had actually to be included to reach a power of 80% to detect an effect size of 0.15 for the expected significant three-way interaction. Accordingly, 16 new participants were added to this initial sample to reach 70 participants in total (mean age = 19.4 years, SD = 2.3, 7 males). These 16 participants received 12 euro as compensation. They all had normal or corrected-to-normal vision, and no history of psychiatric or neurological disorders.

Stimuli and task

Participants were seated in front of a computer monitor and performed a speeded Stroop task that was designed to control for effects of feature repetition and contingency learning (Weissman, Jiang, & Egner, 2014). For each trial, a Stroop stimulus was shown in the center of the computer screen until the participant responded. Participants were instructed to identify the color of the word as fast and accurately as possible using four predefined keys of a response box. These four keys corresponded to four colors (i.e., red, blue, green, yellow). More specifically, they used their left middle finger to respond to red color, left index finger to blue color, right index finger to green color, and right middle finger to yellow color.

The Stroop stimuli consisted of four words (in Dutch) ("rood"/red, "blauw"/blue, "groen"/green, or "geel"/yellow; font size, 30 points) presented in one out of four possible colors (red, RGB: 255, 0, 0; blue, RGB: 0, 176, 240; green, RGB: 0, 255, 0; yellow, RGB: 255, 255, 0). For a given participant, each word was presented in only two of the four possible colors, however (see below). To rule out contingency learning, a four-alternative forced choice (4-AFC) task was used (Schmidt & Weissman, 2014; Weissman et al., 2014), where two pairs of S–R were created arbitrarily to balance congruent and incongruent trials. Each pair consisted of two words and two colors such that incongruent trials were created for the (incompatible) word–color association within each pair, but not across pairs. According to this rule, 8 stimuli types were created in total (instead of 16 if all combinations were constructed), corresponding to 4 stimuli for congruent trials and 4 stimuli for incongruent trials. Each word was presented equally often in the congruent and incongruent color in each block within each mapping (Mordkoff, 2012).

Reactive control was promoted by having 50% incongruent trials in half of the blocks; a condition labeled "low-conflict frequency" in our study. By comparison, proactive control was increased by having 70% incongruent trials in the other half of the blocks, corresponding to the "high-conflict frequency" condition. Each block included 81 trials. As a result, under low-conflict frequency, each of the eight stimuli was presented ten times. Under high-conflict frequency, each of the 4 congruent stimuli was presented 6 times, while each of the 4 incongruent stimuli was presented 14 times. To rule out feature repetitions across successive trials, the stimuli were systematically alternated across them. This way, we ensured that there was no stimulus (or response) repetition for both goal-relevant (color) and goal-irrelevant (meaning) dimensions.

Procedure

Each trial started with a fixation cross that was used as ITI, with a mean duration of 500 ms (range 400–600 ms). After the fixation cross, the Stroop stimulus was presented in the middle of the screen for 1000 ms or until a response was given, followed by a black screen shown for 700 ms, before either an evaluative or a neutral feedback was presented centrally for 700 ms (see Fig. 1). For the evaluative feedback (Fig. 1a) either a positive feedback signaled by a black tick mark was provided if the response was correct and fast enough (i.e., falling below the response deadline corresponding to an arbitrary time limit, explained in more detail below), or a negative feedback signaled by a black cross was provided if the response was incorrect or too slow (i.e., above this time limit). The neutral feedback (Fig. 1b) signaled by a black square indicated a response had been made, without specific information provided about task performance, however. With regard to the time limit, we used an algorithm previously validated that enforces fast responding (Vocat, Pourtois, & Vuilleumier, 2008; Aarts & Pourtois, 2010). Unknown to participants, the reaction time (RT) cutoff was updated on a trial-by-trial basis to deal with unwanted fatigue or habituation effects throughout the experimental session (see Yang & Pourtois, 2018 for a detailed presentation of the algorithm used).

Before the start of the experiment, participants gave informed consent and performed a practice session that consisted of four blocks comprising 13 trials each. The experimental session consisted of 16 blocks including 81 trials each, divided into four main conditions: low-conflict frequency-evaluative feedback (Condition A), low-conflict frequency-neutral feedback (Condition B), high-conflict frequency-evaluative feedback (Condition C), and high-conflict frequency-neutral feedback (Condition D). Each condition included four blocks that were shown successively ("tetrad"). Low-conflict frequency was used for Conditions A and B but evaluative feedback was presented for Condition A, whereas neutral feedback was used for Condition B. By comparison, high-conflict frequency was used for Conditions C and D, where evaluative feedback was presented in the former but neutral feedback in the latter. Four specific orders were created a priori and counterbalanced across participants: A–D–C–B, B–C–D–A, C–B–A–D, and D–A–B–C. Although participants could not rely on the trial-by-trial feedback to infer their task performance in Conditions B and D, however, negative and positive feedback (depending

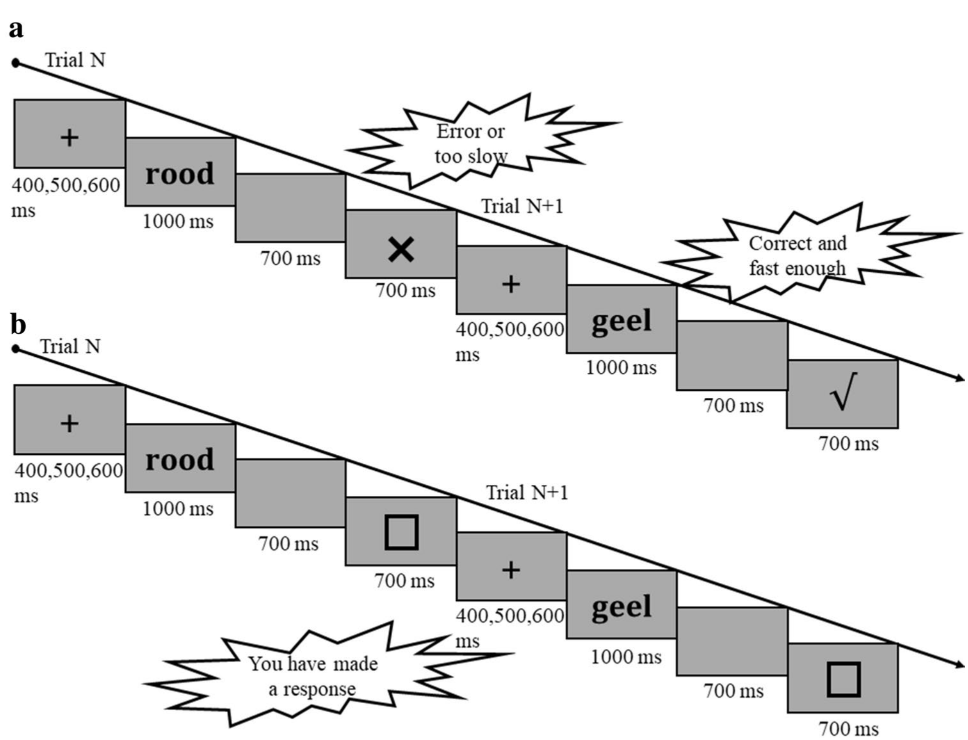

Fig. 1 Experimental procedure. Each trial started with a fixation cross (that lasted on average 500 ms), followed by the Stroop stimulus. In half of the blocks, incongruent trials were more frequent than congruent ones, yielding proactive control. In the other half, the same frequency of congruent and incongruent trials was used, generating reactive control. A blank screen ensued, before either an evaluative feedback (**a**) or a neutral feedback (**b**) was presented in different blocks. The figure shows an example of a cI trial for these two main conditions

on actual speed and accuracy) were registered online (and used offline for data analysis) using the same response deadline as in Conditions A and C. As a result, the blocks with either evaluative or neutral feedback were matched in terms of proportion of negative feedback received (see Table 1). Hence, evaluative and neutral feedbacks only differed in terms of motivational significance of the feedback, being high (evaluative feedback) or absent (neutral feedback), while trial selection was roughly balanced between them. For Conditions A and C, a general feedback was provided at the end of each block, indicating 'the number of trials associated with too slow RTs', 'the number of trials associated with response errors'. No such general feedback was provided at the end of each block for Conditions B and D. At the start of each block, participants were encouraged to make accurate and fast responses. In between blocks, self-paced breaks were allowed. Stimuli were shown in a pseudo-random order within each block to lead to the same number of congruent–Congruent (cC), congruent–Incongruent (cI), incongruent–Congruent (iC) and incongruent–Incongruent (iI) trials. In low-conflict frequency blocks (A and B), this was easily achieved. However, as more incongruent than congruent trials were used in high-conflict frequency blocks (C and D), there were thus more iI trials available (44 trials per block) but fewer trials for cC, cI, iC trials (12 trials per block for each of them). Stimuli presentation and data recording were controlled using E-Prime (Version 2.0; Psychology Software Tools Inc., Sharpsburg, PA).

Questionnaires

Positive and negative affect schedule

A Dutch version of the positive and negative affect schedule (PANAS) was used to measure possible changes in negative/positive emotion between the four different conditions. We analyzed possible changes in negative affect using this scale as we recently found that it increased conflict adaptation (Yang & Pourtois, 2018). The scale consists of 20 words that describe different feelings and emotions (10-item for negative affect, 10-item for positive affect) (Watson et al., 1988). The PANAS was administered at the end of the practice session for the first time. It was then re-administered after each tetrad to measure the corresponding change in mood depending on the specific condition (A, B, C or D). Participants were asked to report their subjective feelings by rating the items on a 5-point scale ranging from 1—*Very slightly* or *not at all* to 5—*Extremely*. In addition, the order of these 20 items was alternated across the five measurement points to reduce the use of any predefined response strategy, or the anticipation of specific emotional words.

PSWQ At the end of the experiment, we also administered the Dutch version of the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) and the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) to perform exploratory analyses between CSE and the disposition to worry, as well as the strategies used by the subjects to regulate their emotions (with the distinction made between reappraisal and suppression).

Table 1 Proportion (expressed in percentage) of negative feedback for blocks with evaluative vs. neutral feedbacks, separately for the low and high-conflict frequency

	50% of incongruency		70% of incongruency	
	Evaluative FB (%)	Neutral FB (%)	Evaluative FB (%)	Neutral FB (%)
After congruent	55.73	55.63	55.75	55.86
After incongruent	61.5	61.06	59.69	58.83

Data analyses

Although we focused primarily on the CSE, we also analyzed the congruency effect (CE, see Supplementary materials). For the CSE, the first trial of each block, error trials, post-error trials, and outlier trials (i.e., RTs ± 3 SD from the condition-specific mean, calculated for each subject separately) were excluded from further analyses, leading to a total of 29% of trials excluded.

Mean RT was computed for each condition separately. Mean RTs were submitted to an analysis of variance (ANOVA) with conflict frequency (low vs. high), feedback type (evaluative vs. neutral), previous congruency (congruent vs. incongruent), and current congruency (congruent vs. incongruent) as within-subject factors. We also analyzed and reported the error rates (see "Results" section) using the same statistical model although our main prediction concerned RT speed but not accuracy.

Subjective ratings

The values of negative and positive affect were obtained from the sum of scores on negative and positive items, respectively. The resulting PANAS values were then submitted to an ANOVA with conflict frequency (low vs. high), feedback type (evaluative vs. neutral), and affect (negative, positive) as within-subject factors.

Exploratory correlation analyses between CSE and subjective ratings

To determine whether the CSE was influenced by negative affect defined as state (PANAS) or trait (PSWQ), as well as its regulation (ERQ where we separated suppression from reappraisal), we performed a stepwise regression analysis. In the model, the CSE obtained for Condition A (low-conflict frequency when evaluative feedback was used) was included as main depend variable together with PANAS, PSWQ, cognitive reappraisal (one subscale of the ERQ), and suppression (the other subscale of the ERQ) as predictor variables. This regression analysis was based on 69 participants since the data of one participant was missing.

A standard alpha level of 0.05 was used for all statistical tests.

Results

RTs

The ANOVA showed that the main effect of conflict frequency was marginally significant, $F(1, 69) = 3.525$, $p = .065$, $\eta_p^2 = 0.049$, with faster RTs in high than low-conflict frequency conditions. The main effect of Feedback type was significant, $F(1, 69) = 72.237$, $p < .001$, $\eta_p^2 = 0.511$, with faster RTs in blocks where evaluative feedback was used, relative to neutral feedback. The main effect of Previous congruency was significant, $F(1, 69) = 7.766$, $p = .007$, $\eta_p^2 = 0.101$, with faster RTs following incongruent than congruent trials, as well as the main effect of current congruency, $F(1, 69) = 128.117$, $p < .001$, $\eta_p^2 = 0.650$, with faster RTs for congruent than incongruent trials. Furthermore, the three-way interaction of conflict frequency, previous congruency, and current congruency was significant, $F(1, 69) = 6.760$, $p = .011$, $\eta_p^2 = 0.089$, indicating that the CSE was modulated by conflict frequency. Crucially, the four-way interaction between conflict frequency, feedback type, previous congruency and current congruency was significant too, $F(1, 69) = 4.928$, $p = .030$, $\eta_p^2 = 0.067$, indicating that CSE was influenced concurrently by conflict frequency throughout the block and the type of feedback information used at the single trial level (Fig. 2). To better characterize this four-way interaction, we ran two separate ANOVAs with conflict frequency, previous congruency, and current congruency, separately for evaluative and neutral feedback. For evaluative feedback, the main effect of conflict frequency was significant, $F(1, 69) = 5.925$, $p = .018$, $\eta_p^2 = 0.079$. The current congruency was significant, $F(1, 69) = 86.159$, $p < .001$, $\eta_p^2 = 0.555$. Importantly, the three-way interaction was highly significant, $F(1, 69) = 13.209$, $p = .001$, $\eta_p^2 = 0.161$, indicating that the CSE was modulated by conflict frequency, when the feedback type was evaluative. To further examine this, we therefore, performed planned comparisons, separately for low and high-conflict frequency. For low-conflict frequency (Fig. 2), the

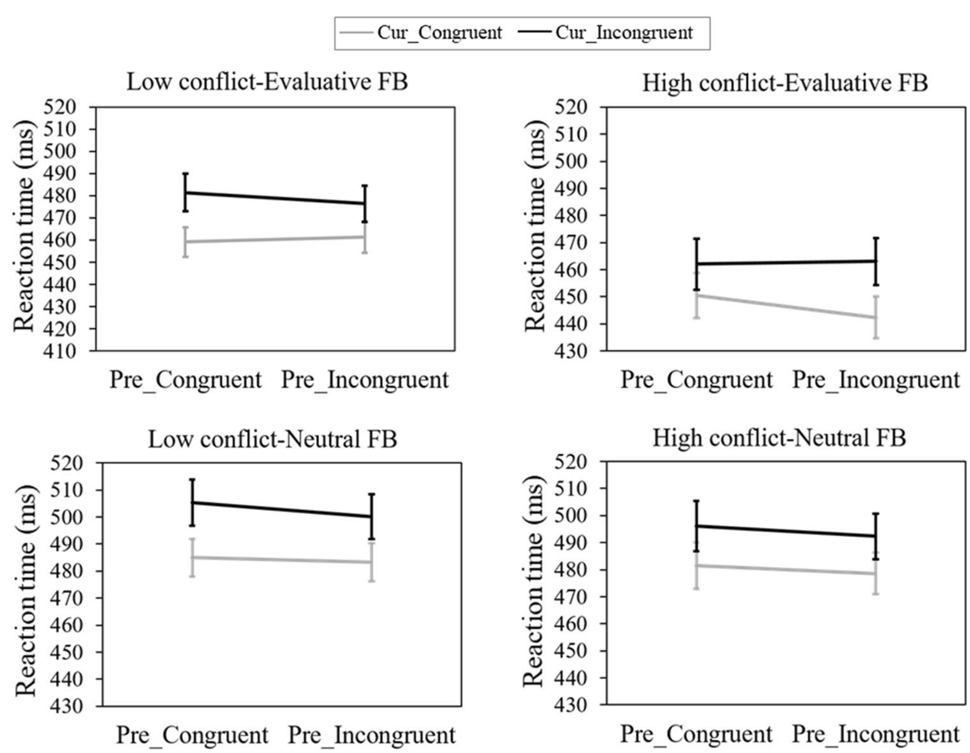

Fig. 2 Behavioral results for the CSE. Low-conflict evaluative FB. A normal CSE was observed under low-conflict frequency, when evaluative feedback was used selectively. High-conflict evaluative FB. Under high-conflict frequency when evaluative feedback was used, a different sequence effect was found whereby cC trials led to a systematic slowing done compared to iC trials. Low-conflict neutral FB. No reliable CSE was observed under low-conflict frequency when neutral feedback was used. High-conflict neutral FB. No reliable CSE was observed under high-conflict frequency when neutral feedback was used. The error bar represents the standard error (SE). ***$p < .001$, **$p < .01$, *$p < .05$

current congruency was significant, $F(1, 69) = 47.944$, $p < .001$, $\eta_p^2 = 0.410$, as well as the interaction of previous with current congruency, $F(1, 69) = 6.428$, $p = .014$, $\eta_p^2 = 0.085$. This effect was explained by faster response for iI compared with cI, $t(69) = -2.419$, $p = .018$, 95% CI [−9.27, −0.89], whereas no difference between cC and iC was observed, $t(69) = -0.868$, $p = .388$, 95% CI [−7.44, 2.93]. By comparison, for high-conflict frequency (Fig. 2), the previous congruency effect was significant, $F(1, 69) = 4.554$, $p = .036$, $\eta_p^2 = 0.062$, the current congruency too, $F(1, 69) = 54.644$, $p < .001$, $\eta_p^2 = 0.442$, as well as the interaction of previous with current congruency, $F(1, 69) = 5.690$, $p = .020$, $\eta_p^2 = 0.076$. This effect was explained by faster response for iC compared with cC, $t(69) = -2.977$, $p = .004$, 95% CI [−13.51, −2.67], whereas no difference was observed between cI and iI was observed, $t(69) = -0.413$, $p = .681$, 95% CI [−5.59, 3.67].

For neutral feedback (see Fig. 2, lower panel), both the previous congruency, $F(1, 69) = 6.362$, $p = .014$, $\eta_p^2 = 0.084$, and the current congruency, $F(1, 69) = 96.858$, $p < .001$, $\eta_p^2 = 0.584$, were significant. No any other reliable effect was found, $Fs(1, 69) \leq 2.054$, $ps \geq .156$, $\eta_p^2s \leq 0.029$. Last, we also performed a control analysis (see Supplementary Materials) to confirm that the modulation of the CSE by conflict frequency and feedback type was not simply due to systematic changes occurring at the trial n-1 level.

Error rates

The ANOVA revealed a significant main effect of Feedback type, $F(1, 69) = 41.932$, $p < .001$, $\eta_p^2 = 0.378$, with higher error rates for evaluative than neutral feedback; a significant main effect of previous congruency, $F(1, 69) = 20.628$, $p < .001$, $\eta_p^2 = 0.230$, with higher error rates following congruent relative to incongruent trials. This analysis also showed that the interaction between feedback type with previous congruency was significant, $F(1, 69) = 13.932$, $p < .001$, $\eta_p^2 = 0.168$. This effect was explained by higher error rates following congruent than incongruent trials when neutral feedback was used, $t(69) = 6.398$, $p < .001$, 95% CI [0.151, 0.289], whereas there was no significant difference between congruent and incongruent trials when evaluative feedback was used, $t(69) = 0.046$, $p = .964$, 95% CI [−0.008, 0.008]. In addition, the significant interaction of previous congruency with current congruency was significant, $F(1, 69) = 4.658$, $p = .034$, $\eta_p^2 = 0.063$. This effect was driven by higher error rates for cC than iC trials, $t(69) = 4.195$, $p < .001$, 95% CI [0.009, 0.026], whereas there was no significant difference between cI and iI trials, $t(69) = 1.382$, $p = .171$, 95% CI [−0.002, 0.116]. No other significant effects were found, $Fs(1, 69) \leq 3.596$, $ps \geq 0.062$, $\eta_p^2s \leq 0.050$.

Subjective ratings

The ANOVA showed a significant effect of feedback type, with higher subjective ratings for conditions with evaluative feedback (A and C) compared to neutral feedback (B and D), $F(1, 69) = 12.123$, $p = .001$, $\eta_p^2 = 0.149$. This analysis also showed a significant effect of Affect, with higher subjective ratings for positive than negative affect, $F(1, 69) = 22.102$, $p < .001$, $\eta_p^2 = 0.243$. Further, the interaction of conflict frequency with affect was significant, $F(1, 69) = 6.295$, $p = .014$, $\eta_p^2 = 0.084$. This interaction indicated lower positive feelings in the low (A and B) compared with high (C and D) conflict frequency conditions, $t(69) = -1.966$, $p = .053$, 95% CI [−2.547, 0.1859], whereas negative feelings did not differ between them, $t(69) = 1.612$, $p = 1.112$, 95% CI [−0.149, 1.406]. The interaction of feedback type with affect was significant as well, $F(1, 69) = 16.281$, $p < .001$, $\eta_p^2 = 0.191$. This interaction translated higher negative feelings in conditions (A and C) with evaluative-feedback compared with conditions without (B and D), $t(69) = 5.037$, $p < .001$, 95% CI [1.631, 3.769], whereas the opposite pattern was found for positive feelings, $t(69) = -2.653$, $p = .010$, 95% CI [−1.915, −0.271] (see Fig. 3a). Post hoc paired *t* tests showed that levels of negative feelings during the practice session was significantly lower than that in conditions with the evaluative feedback (A and C), $t(69) \geq 2.138$, $ps \leq .036$. By comparison, levels of positive feelings during the practice session were significantly higher than those of any other experimental condition, $ts(69) \geq 7.876$, $ps \leq .001$ (see Fig. 3a).

Exploratory correlation analyses

When cognitive reappraisal was entered alone into the regression model, it predicted significantly the CSE, $F(1, 68) = 8.076$, $p = .006$. Noteworthy, we used the CSE as dependent variable computed in the condition with evaluative feedback under low-conflict frequency because it was the condition where it was the most clearly expressed (see Fig. 3b). Approximately, 13% of the variance of the CSE could be accounted by cognitive reappraisal. More specifically, cognitive reappraisal was negatively related to the CSE, unstandardized $\beta = -1.402$, $t(68) = -2.842$, $p = .006$, CI 95% [−2.386, −0.417]. By comparison, we did not find a significant correlation between suppression and the CSE (see Fig. 3c). When comparing these two correlation coefficients directly, a significant difference was found, using a one-tailed test, $z = 1.73$, $p = .04$. The PSWQ and PANAS did not predict the CSE, $t(68) \leq 0.906$, $p \geq .368$. See the correlation matrix for all variables (CSE, Reappraisal, Suppression, PSWQ, PANAS) in Table 2.

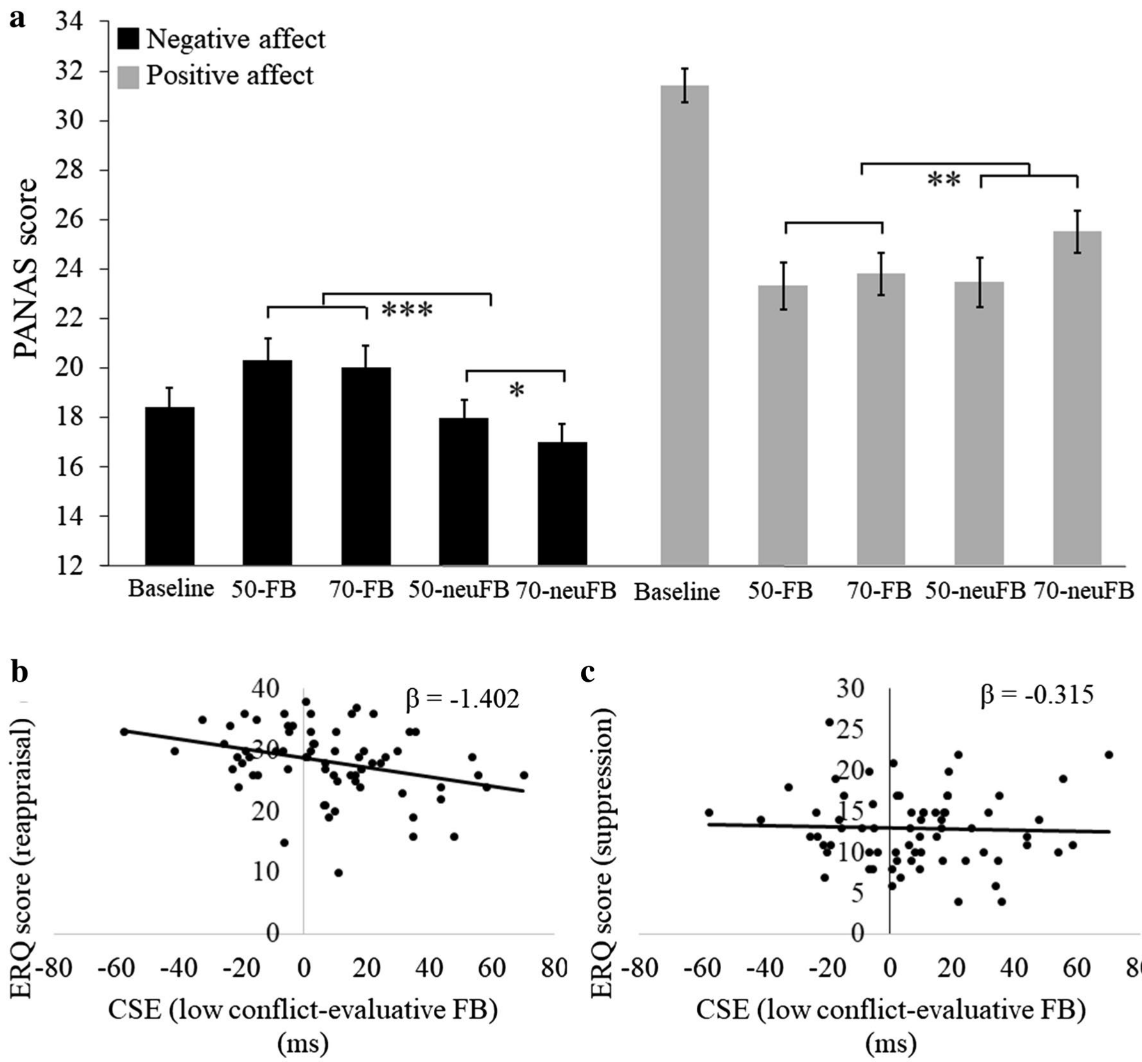

Fig. 3 Subjective ratings and correlations between affect and task performance (CSE). **a** PANAS results showed subjective positive affect was lower in the low compared with high-conflict frequency conditions, with no difference in negative affect between them. Subjective negative affect was higher in conditions with evaluative feedback compared with conditions without the pattern for positive affect was opposite. **b** A significant negative correlation was found between cognitive reappraisal and CSE (when computed for the condition with low-conflict frequency and the use of evaluative feedback). **c** No significant correlation was found between suppression and CSE in this condition. The error bar represents the standard error (SE), $^{**}p < .01$

Table 2 Correlation matrix for all variables

	CSE	Reappraisal	Suppression	PSWQ	PANAS
CSE	1	− 0.328**	− 0.04	− 0.091	0.036
Reappraisal	− 0.328**	1	− 0.053	− 0.029	− 0.125
Suppression	− 0.04	− 0.053	1	− 0.082	− 0.043
PSWQ	− 0.091	− 0.029	− 0.082	1	0.076
PANAS	0.036	− 0.125	− 0.043	0.076	1

$^{**}p = .006$

Discussion

The current study sought to explore the involvement of reactive vs. proactive control in conflict-related trial-by-trial adjustments, as reflected by the CSE. To this aim, we used a variant of the Stroop task where we controlled for effects of feature repetition and contingency learning across trials (Schmidt & Weissman, 2014; Weissman et al., 2014). We computed the CSE following standard practice, and alternated conflict frequency across blocks. Reactive control was presumably increased when conflict frequency was set to 50%, whereas proactive mechanisms were likely at stake when conflict frequency was set to 70% (Braver, Gray, &

Burgess, 2007, Braver, 2012). Orthogonally to this main variable, we manipulated the nature of the feedback provided on a trial-by-trial basis, being either explicitly evaluative (i.e., informing about self-efficacy) or totally neutral (i.e., valence unspecific and not informing about self-efficacy), while being both always contingent on response execution. Our results confirm the hypothesis that the CSE was influenced by conflict frequency and feedback type concurrently. In the evaluative feedback condition, the CSE was influenced by conflict frequency. There: a normal CSE was observed when conflict frequency was low, whereas a qualitatively different sequence effect was observed when conflict frequency was high. In this latter condition, the interaction between previous and current congruency was driven by the difference between cC and iC rather than between cI and iI. In contrast, the modulatory influence of conflict frequency on the CSE was abolished when neutral feedback was used throughout the block.

When the feedback was evaluative, a typical CSE was observed if conflict frequency was low. Presumably, the performance-contingent feedback enhanced conflict-driven control processes operating at a local level. This boost in CC might stem from changes in specific motivation processes (Van Steenbergen, Band, & Hommel, 2015), especially if the previous trial was conflict-related (Hinault, Badier, Baillet, & Lemaire, 2017). Interestingly, in high-conflict frequency, the previous and current congruency also interacted with one another, revealing a systematic slowing done for cC relative to iC trials. These two effects accord well with the DMC model (Braver, Gray, & Burgess, 2007, Braver, 2012) assuming that changes in conflict frequency alter the balance between proactive and reactive control. When conflict frequency was high, the cC sequence was probably unexpected and/or violating a specific mind set or preparation process geared towards conflict processing, resulting in turn in a systematic slowing done for these infrequent cC trials (Gonthier, Braver, & Bugg, 2016).

By comparison, when encountering neutral feedback, no clear sequence effect was observed, irrespective of the specific conflict frequency used. This result is compatible with earlier findings showing that at low or moderate conflict frequency, the CSE disappears after neutral, compared to evaluative feedback (Braem, Verguts, Roggeman, & Notebaert, 2012). At high-conflict frequency, we propose that neutral feedback might block the use of proactive control because the motivational significance of conflict is reduced in this condition.

From a cognitive perspective, the modulation of the CSE by the feedback type for low-conflict frequency might be explained by the involvement of specific motivational or attentional processes operating at a local level (Botvinick, Cohen, & Carter, 2004). However, the elicitation of negative affect at the subjective level when encountering evaluative feedback, as the PANAS results clearly showed, might also provide an important ingredient to foster enhanced (reactive) control (Yang & Pourtois, 2018). Earlier studies already demonstrated strong ties between conflict processing and negative affect; conflict-related stimuli being usually perceived as aversive events (Dreisbach & Fischer, 2012; Fritz & Dreisbach, 2013; Schouppe, Houwer, Ridderinkhof, & Notebaert, 2012, 2015). Yet, it is important to underscore that this enhanced negative affect associated with the use of evaluative feedback had to occur in a context of reactive control to influence the CSE. Accordingly, the evaluative feedback likely provided participants with a valuable motivational signal or cue that could be used to foster CC (Inzlicht, Bartholow, & Hirsh, 2015), especially when it operated reactively and locally. Alternatively, this evaluative feedback likely promoted a fast associative learning under reactive control, which in turn enhanced CC, as recently advocated (Abrahamse, Braem, Notebaert, & Verguts, 2016).

Previous findings already reported a preferential link between negative affect and reactive, as opposed to proactive control (West, Choi, & Travers, 2010; Braver et al., 2007; Shackman et al., 2011). Our new results lend support to this assumption, albeit indirectly only. Indeed, we did not observe increased negative affect at the PANAS level under reactive (low-conflict frequency) compared to proactive (high-conflict frequency) control, but decreased positive affect, selectively. However, it should be noted that the relationship between positive and negative affect, as obtained using the PANAS, is usually complex and cannot simply be captured by a negative correlation for example (Harding, 1982; Warr, Barter, & Brownbridge, 1983; Rossi & Pourtois, 2012). As suggested by Diener and Emmons (1984), positive and negative affect are not necessarily negatively related, but instead, they can be mutually exclusive because they are unlikely to occur at the same time. Hence, it appears parsimonious to conclude that the observed decreased positive affect in low compared with high-conflict frequency in our study only indirectly supports the view that negative affect is positively related to the engagement of reactive control (West, Choi, & Travers, 2010).

Noteworthily, we also found that cognitive reappraisal negatively correlated with the CSE. In contrast, this link was not found with CC when suppression was considered as alternative emotion regulation strategy in our study. Reappraisal is usually conceived as an adaptive emotion regulation strategy enabling individuals to downplay the impact of negative events or emotions by changing their meaning, usually in a way which is proactive or antecedent relative to them (Gross, 2002). Hence, these correlation results suggest that dispositions related to the use of specific regulation strategies characterized by proactive processes can influence CC. More specifically, our new results suggest that participants who usually used reappraisal in daily life actually had a lower CSE, as if they used implicitly proactive control during task execution, even though reactive control was actually elicited. Hence, trial-by-trial adjustments in control were influenced by reappraisal, this disposition likely producing a shift from reactive to proactive control processes. Therefore, besides the context defined by the frequency of incongruent trials and the use of evaluative feedback to reinforce it (or the lack thereof), inter-individual differences in specific dispositions, here with a focus on emotion regulation and more specifically reappraisal eventually combined to determine the engagement of proactive vs. reactive control strategies to deal with conflict (Braver et al., 2007). More generally, our new results are compatible with recent data and models available in the literature arguing that emotion regulation, besides conflict processing per se, can dynamically influence CC (Dignath & Eder, 2015; Dreisbach & Fischer, 2015). In this context, it appears, therefore, important to consider and model carefully inter-individual differences in emotion regulation, or other dispositions, when exploring this fundamental process as they appear to influence it substantially (see also Braver, 2012; Braver, Cole, & Yarkoni, 2010; Egner, 2011).

A limitation warrants comment. Although we used stringent methodological guards against stimulus repetition, response repetition and contingency learning with the elected Stroop task (see Weissman, Jiang, & Egner, 2014), it remains hard to exclude the contribution of feature binding to the observed results (Hommel, 2004), especially when conflict frequency was high (Blais & Bunge, 2010; Bugg, Jacoby, & Toth, 2008). The systematic slowing down in RTs for cC compared with iC trials, and iI compared with cI trials in this condition might both be explained by feature binding to some extent, in the sense that the processing of stimuli associated with conflict, because being more frequently encountered in these blocks, was in turn facilitated somehow (Blais & Bunge, 2010; Bugg, Jacoby, & Toth, 2008). Future studies using factorial manipulations of feature binding and conflict frequency are needed to model and assess their respective contributions to the CSE.

To sum up, the results of this study confirmed a preferential link between conflict adaptation (i.e., the CSE) and the use of reactive control operating at a local level, being potentiated with the use of evaluative feedback contingent on task performance. Dissociable trial-by-trial adjustments as a function of conflict processing were found when proactive control was elicited. Moreover, the transient elicitation of negative affect with this evaluative feedback likely contributed to foster conflict adaptation, yet when reactive control dominated, suggesting that negative affect alone was not sufficient to create or change conflict adaptation. Interestingly, reappraisal, when considered as a disposition, substantially reduced conflict adaptation as if this regulation strategy promoted the use of proactive control even though the context-favored reactive control. Accordingly, we propose that CC is flexible and can yield different manifestations at the behavioral level depending on the specific balance between proactive and reactive control modes, as well as the activation of specific affective and motivational processes related to specific dispositions.

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Compliance with ethical standards

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

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ghent University and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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

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