Mechanisms of Negative Emotion in Conflict Adaptation: Separation and Integration Perspectives

Authors: Yang Qian, Yang Qian

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Abstract

How negative emotions influence conflict adaptation has long been a topic of extensive concern among researchers in the field. Depending on the source of negative emotions (externally manipulated versus intrinsically inherent to conflict), discussions on this issue can be approached from the perspectives of dissociation and integration between cognition and emotion. From the dissociation perspective, negative emotions manipulated external to conflict (external negative emotions) operate independently of the conflict processing mechanism, influencing conflict adaptation through the emotional processing system or an individual' s own motivational/arousal levels. Recent studies have found that conflict processing automatically generates negative emotions (intrinsic negative emotions), implying an intrinsic association between cognitive conflict and negative emotions; thus, intrinsic negative emotions can be regarded as another effective source that triggers conflict adaptation. From the integration perspective, negative emotions manipulated within conflict (intrinsic negative emotions) are highly integrated into the conflict processing mechanism, functioning similarly to conflict information and directly triggering conflict adaptation by intrinsically facilitating goal-directed behavior. The discussion of this topic deepens our understanding of how negative emotions act upon the conflict adaptation process and also provides a novel perspective for exploring the integration processes and mechanisms of cognitive and emotional systems. On this basis, we also propose several feasible directions for future research.

Full Text

The Role of Negative Affect in Conflict Adaptation: Separated vs. Integrated Perspectives

YANG Qian
Institute of Brain and Psychological Sciences, Sichuan Normal University, Chengdu 610066, China

Abstract

How negative affect influences conflict adaptation has long been a central concern for researchers in the field. Depending on whether the source of negative affect is manipulated externally versus inherent to the conflict itself, this question can be examined from two distinct perspectives: the separation and integration of cognition and emotion. From the separation perspective, negative affect manipulated outside of conflict (incidental negative affect) operates independently of conflict processing, influencing conflict adaptation through the emotional processing system or by modulating an individual' s motivational/arousal levels. Recent findings have revealed that conflict processing automatically generates negative affect (integral negative affect), suggesting an intrinsic link between cognitive conflict and negative emotion. Consequently, integral negative affect can be considered another valid source for triggering conflict adaptation. From the integration perspective, negative affect that arises within conflict (integral negative affect) is deeply integrated into conflict processing, functioning similarly to conflict information by directly promoting goal-directed behavior and thereby eliciting conflict adaptation. This discussion deepens our understanding of how negative affect operates in conflict adaptation and provides a novel framework for exploring the integration processes and mechanisms between cognitive and emotional systems. Based on this synthesis, we propose several promising directions for future research.

Keywords: conflict adaptation, negative affect, cognitive control, affective-signaling hypothesis

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Corresponding Author: YANG Qian, E-mail: qianyang_psy@163.com

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1. Introduction

In daily life, to efficiently and accurately accomplish goal-directed tasks, individuals must continuously monitor and regulate sources of interference, adjusting their responses based on prior experience to optimize behavioral performance.

This monitoring and regulatory capacity reflects human adaptability and plays a crucial role across numerous domains of work, learning, and life [?, ?]. To investigate the underlying mechanisms of this adaptability, researchers have employed conflict processing tasks (e.g., Stroop, Flanker, and Simon) to examine the dynamic processing and regulation of conflict across trials. These studies consistently demonstrate that individuals resolve conflict more effectively in current trials following conflict in previous trials—a phenomenon known as conflict adaptation [?, ?].

Conflict adaptation depends on cognitive control systems [?, ?, ?], and manipulating cognitive factors such as conflict magnitude or intensity can modulate cognitive control \cite{张孟可等，2021}. Beyond these cognitive factors, negative affect represents another important regulator of cognitive control [?, ?, ?], and how it influences conflict adaptation has garnered considerable attention. Early perspectives maintained a clear boundary between emotional and cognitive systems [?, ?], with most research adopting a separation perspective to examine how negative affect manipulated outside of conflict (incidental negative affect, [?, ?]) influences conflict adaptation through the emotional processing system [?, ?]. However, recent studies have found that conflict processing automatically generates negative affect, suggesting that emotion can be integrated into cognitive control processes [?, ?, ?]. This automatically generated negative affect, termed "integral negative affect" [?, ?], points to an intrinsic association between negative emotion and conflict processing. Similar to conflict information, integral negative affect can serve as an input signal that directly triggers conflict adaptation [?, ?]. Accordingly, this paper addresses the question of "how negative affect functions in conflict adaptation" from both separation and integration perspectives, based on the source of negative affect (externally manipulated vs. internally generated).

2. External Negative Affect Modulates (Cognitive) Conflict Adaptation: The Separation Perspective

Traditional views have long held that the emotional "hot" system operates independently of cognitive control [?, ?], and that cognitive control tasks themselves do not involve emotional processing. From this separation perspective, researchers have manipulated negative affect outside of conflict (through negative emotional stimulus processing or negative mood states) to explore its impact on conflict adaptation and underlying mechanisms. According to the conflict-monitoring model [?, ?], conflict adaptation reflects dynamic regulation from conflict "monitoring" in previous trials to conflict "resolution" in current trials. In this process, conflict information serves not only as the primary trigger for cognitive control but also as the interference that cognitive control must regulate and resolve (Figure 1A). When negative affect is manipulated outside of conflict, its influence on conflict adaptation occurs primarily through the emotional processing system's impact on cognitive control (Figure 1A). Thus, this "separation" operates at two levels: first, the separation between external negative affect and conflict itself; second, the separation between the emotional processing system and the cognitive control system upon which conflict processing and adaptation depend.

Figure 1. A. Within the conflict-monitoring framework (Conflict-monitoring theory, [?, ?]), conflict information is the primary source triggering conflict adaptation, with negative affect manipulated outside of conflict modulating adaptation through the emotional processing system and individual motivational/arousal levels. B. Within the affective-signaling hypothesis framework (Affective Signaling Hypothesis; [?, ?]), negative affect generated during conflict processing (illustrated by unhappy faces) serves as the primary source triggering conflict adaptation. C. Both conflict information and its associated integral negative affect are valid sources for eliciting conflict adaptation.

2.1 The Impact of External (Incidental) Negative Affect on Conflict Adaptation

Research has primarily investigated how negative affect influences conflict adaptation by manipulating either negative emotional stimulus processing or negative mood states. In some studies, negative emotional stimuli (including negative images or negative feedback) were presented after congruent or incongruent trials in conflict tasks to examine their effects on conflict adaptation. Comparative findings reveal that when negative emotional stimuli are task-relevant (based on response time and accuracy), conflict adaptation is enhanced [?, ?, ?]. However, when such stimuli are task-irrelevant, the conclusions are mixed: some studies show that task-irrelevant negative affect enhances conflict adaptation [?, ?, ?, ?, ?, ?], others demonstrate it impairs adaptation [?, ?, ?], and one study found no effect on conflict adaptation [?, ?, ?]. Integrating these findings, the relevance of negative emotional stimuli to the current conflict task emerges as a critical factor determining whether negative affect enhances or impairs conflict adaptation.

Unlike stimulus processing, negative mood states refer to induced emotional states that can persist for extended periods. Temporally, negative emotional stimulus processing and mood states operate on short-term versus long-term dimensions: the former represents a discrete process with brief duration, while the latter constitutes a continuous process with longer duration. As experiments progress, repeated negative emotional stimulus processing gradually "transforms" into a continuous mood state \cite{罗培等，2016}. Luo et al. (2016) used a Flanker task to induce conflict processing and adaptation, presenting negative emotional images after each congruent or incongruent trial to examine their effects. Their results showed that negative affect' s impact on conflict adaptation was modulated by processing stage: negative affect generated in early stages impaired conflict adaptation, whereas that generated in later stages enhanced it. This difference arises because early-stage negative affect relies more on valence processing of task-irrelevant emotional stimuli, while later-stage negative affect can be considered a physiological arousal-dominant mood state. To further investigate the influence of negative mood states, studies have induced participants' negative moods before conflict tasks using music, film clips, or stress tests [?, ?, ?, ?, ?, ?]. Subsequent conflict tasks consistently showed enhanced conflict adaptation across these similar contexts.

2.2 Underlying Mechanisms of External Negative Affect in Modulating Conflict Adaptation

Both negative emotional stimulus processing and mood states can activate the emotional processing system, correspondingly enhancing activity in subcortical emotion-related brain regions including the amygdala, hippocampus, and thalamus [?, ?]. Due to the processing advantage of emotional information [?, ?], emotional signals can rapidly transmit to cognitive control-related brain regions such as the dorsolateral prefrontal cortex (DLPFC) [?, ?]. Consequently, when negative affect is task-relevant, it can more effectively trigger top-down cognitive control processes, thereby promoting conflict adaptation. Conversely, when negative affect is task-irrelevant, its processing reduces cognitive control levels, impairing adaptation. From a cognitive resource perspective, the relevance of negative affect to conflict processing reflects the extent to which emotional and cognitive processes can share cognitive resources [?, ?]. Within the same task, if more cognitive resources are allocated to processing one type of stimulus, fewer resources remain for processing another [?, ?, ?]. Following this logic, when processing-advantaged negative affect is task-relevant, the cognitive resources devoted to processing it also contribute to conflict regulation, facilitating adaptation. When the two are unrelated, their processing competes for resources, and because negative affect holds a processing advantage [?, ?], its excessive consumption of resources needed for conflict regulation impairs conflict adaptation [?, ?].

Regarding negative mood states, they resemble affective dispositions, reflecting an individual' s physiological arousal and vigilance level [?, ?]. As arousal and vigilance increase, negative affect serves a signaling function, alerting the individual to trigger top-down control processes in the corresponding context [?, ?]. Simultaneously, motivational levels increase, enhancing reactive control and promoting conflict adaptation [?, ?, ?, ?]. According to mood congruency theory [?, ?], individuals show processing biases toward stimuli consistent with their current mood state: when in positive moods, they more readily attend to positive information, whereas in negative moods, negative thoughts and information receive greater attention. This negative processing bias subsequently influences various higher-order cognitive components including attention, memory, and reasoning [?, ?, ?].

In summary, negative affect manipulated outside of conflict modulates conflict adaptation. As shown in Figure 1A, negative emotional stimulus processing interacts with cognitive control through the emotional processing system, while negative mood states regulate adaptation through individual motivation, arousal, or vigilance levels. Both approaches modulate cognitive control-based conflict adaptation via a "third party," reflecting a degree of separation between emotional processing and cognitive control systems.

3. The Intrinsic Link Between Negative Affect and Cognitive Conflict

The conflict-monitoring model [?, ?] posits that conflict information is the primary source triggering cognitive control. From the separation perspective, conflict processing and adaptation involve only cognitive control systems, with negative affect playing an indirect modulatory role. Interestingly, recent research has found that negative affect automatically emerges during cognitive conflict processing [?, ?, ?], indicating that conflict processing engages not only the cognitive "cold" system but also the emotional "hot" system. This automatically generated negative affect, termed "integral negative affect" [?, ?], points to an intrinsic association between conflict processing and negative emotion. Evidence from behavioral, physiological, and neuroimaging studies supports this view.

3.1.1 Behavioral Evidence

The notion that negative affect spontaneously accompanies conflict processing was first demonstrated in affective-priming studies [?, ?]. According to evaluative priming theory [?, ?], the emotional valence of a prime influences subsequent evaluations of target stimuli. For instance, negative primes facilitate responses to negative targets while slowing responses to positive targets. Following this logic, some studies have used conflict as an (emotional) prime to investigate its emotional processing characteristics. Specifically, experiments require participants to evaluate the emotional valence of target words (positive or negative) presented after prime stimuli (conflict or non-conflict trials). Multiple studies consistently show faster responses to negative targets following conflict primes compared to non-conflict primes [?, ?, ?, ?]. Subsequently, in the Affect Misattribution Procedure (AMP; [?, ?]), participants judge the valence (negative vs. positive) of neutral target words following conflict or non-conflict trials. Results indicate that neutral words presented after conflict stimuli are more likely to be judged as negative rather than positive [?, ?, ?, ?]. These findings demonstrate that conflict stimuli facilitate negative emotional processing, indirectly suggesting that conflict processing automatically evokes negative affect.

3.1.2 Physiological Evidence

Negative affect processing is often accompanied by physiological changes, which provide more objective indicators than behavioral responses [?, ?]. Research shows that during conflict tasks, incongruent trials (compared to congruent trials) are associated with various physiological responses: pupil dilation [?, ?, ?, ?, ?], enhanced skin conductance [?, ?], increased heart rate deceleration [?, ?], and changes in corrugator supercilii activity [?, ?]. These different physiological markers reflect distinct cognitive processes engaged during conflict processing. First, skin conductance and corrugator activity respectively reflect arousal and negative valence dimensions of emotional processing [?, ?, ?]. Second, pupil dilation indicates increased demands for cognitive resources and effort in the current task context [?, ?]. Third, heart rate acceleration is closely linked to defensive motivation activation, which prompts individuals to engage specific cognitive processing modes appropriate for negative contexts [?, ?]. Its enhancement during conflict processing partly reflects avoidance of the negative affect generated during conflict [?, ?].

3.1.3 Neural Basis of the Negative Affect-Conflict Link: The Critical Role of dorsal ACC (dACC)

A meta-analysis revealed that both negative affect (e.g., pain) and conflict processing activate the dorsal anterior cingulate cortex (dACC; [?, ?]). The dACC connects not only with frontoparietal cognitive control regions such as the dorsolateral prefrontal cortex (dLPFC) [?, ?] but also with ventral emotion-processing pathways including the amygdala and insula [?, ?]. By linking bottom-up emotional processing with top-down attentional/cognitive control systems, the dACC can be considered a core hub for integrating brain information, providing an anatomical foundation for the integration of negative affect and conflict processing/adaptation [?, ?, ?]. First, numerous studies have confirmed dACC' s prominent role in conflict monitoring and processing [?, ?, ?], showing stronger dACC activity during "incongruent-incongruent" versus "congruent-incongruent" trials in conflict adaptation, indicating enhanced conflict monitoring. Second, behavioral studies show that conflict can prime subsequent negative emotional picture processing, an effect also reflected in dACC activity changes. Braem et al. (2017) employed an affective priming paradigm with a long interval (3.5 s) between conflict primes and emotional pictures, using fMRI to examine whether dACC activity during emotional picture processing was modulated by prime congruency. Results showed significantly reduced dACC activity during negative picture processing following conflict trials, suggesting that after conflict processing, individuals adapt to processing negative pictures sharing the same emotional valence. Additionally, dACC participates in evaluating negative emotional experiences (e.g., frustration) arising from cognitive tasks [?, ?]. Furthermore, Vermeylen et al. (2020) used representational similarity analysis of fMRI data to show that conflict and negative affect processing can be simultaneously represented in dACC. These studies provide direct or indirect evidence for the integration of negative affect and conflict processing at the neural activity level.

3.2 Why Does Conflict Processing Automatically Evoke Negative Affect?

Despite multimodal evidence (behavioral, physiological, neuroimaging) for automatic negative affect generation during conflict processing, we must further clarify why this occurs. During conflict processing, individuals'habitual response tendencies diverge from expected outcomes, creating negative affect associated with goal confusion or increased error likelihood [?, ?]. To better control and resolve conflict, individuals must actively mobilize cognitive resources and invest greater cognitive effort [?, ?]; however, effort itself is aversive [?, ?, ?]. Importantly, behavioral studies show that integral negative affect accompanying conflict processing is brief and automatic [?, ?]. In affective priming paradigms, the facilitative effect of conflict primes on subsequent negative stimuli is only effective at short intervals (< 400 ms) [?, ?, ?]. At longer intervals (800 ms), neutral targets following conflict primes are more likely to be judged as positive rather than negative [?, ?]. These results suggest that conflict processing spontaneously generates more positive affect during this timeframe, leading us to hypothesize that the conflict-negative affect link is constrained by processing stage: in early stages, before conflict is effectively controlled and resolved, higher cognitive load and effort generate more negative affect; in later stages, after effective control, reduced task load and cognitive effort produce more positive affect [?, ?, ?, ?]. In contrast, at the fMRI level, despite a long interval (3.5 s) between conflict and subsequent negative pictures, the facilitative effect remains evident in dACC activity, suggesting a dissociation between behavioral and neuroimaging levels.

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4. Integral Negative Affect Elicits (Cognitive) Conflict Adaptation: An Integrated Perspective

From the separation perspective, conflict information is the primary source of conflict adaptation, with externally manipulated negative affect indirectly modulating adaptation through emotional processing systems or individual states. Further research has revealed the intrinsic link between conflict processing and negative affect: negative affect automatically emerges during conflict processing and can be viewed as an "output" signal. However, negative affect is not merely an output—it also serves as an important "input" source influencing conflict processing [?, ?]. Consequently, investigations of negative affect' s role in conflict adaptation have expanded beyond the separation perspective' s focus on modulatory effects to the integration perspective, which considers integral negative affect as another valid source for triggering adaptation [?, ?, ?]. Researchers have employed various methods to manipulate integral negative affect arising from or analogous to conflict processing, revealing its role in conflict adaptation from multiple angles.

4.1 The Impact of Integral Negative Affect on Conflict Adaptation

4.1.1 Integral Negative Affect Independent of Conflict Elicits Adaptive Control To explore integral negative affect' s influence on conflict adaptation, theoretically we should separate it from conflict information. However, since integral negative affect in this context is generated based on conflict processing, complete separation is difficult. Given that high-load cognitive tasks automatically evoke negative affect [?, ?], researchers have investigated this issue using high-load tasks analogous to conflict. Specifically, studies have used "fluent" versus "disfluent" words as experimental stimuli, analogous to "congruent" versus "incongruent" trials in conflict adaptation paradigms [?, ?]. Like incongruent trials, disfluent word processing—though lacking conflict information—evokes negative affect due to its high cognitive load [?, ?]. By examining whether a "disfluency" adaptation effect analogous to "conflict" adaptation exists, researchers can determine whether integral negative affect from high-load tasks can elicit adaptive effects in the absence of conflict information, thereby inferring its role in conflict adaptation. Results revealed a "disfluency" adaptation effect analogous to conflict adaptation: responses to disfluent words were faster when preceded by disfluent versus fluent trials, demonstrating that integral negative affect itself can elicit adaptive behavioral responses. This finding provides preliminary empirical foundation for subsequent research directly manipulating negative affect generated during conflict processing to examine its impact on conflict adaptation.

4.1.2 Subjective (Emotional) Experience Based on Conflict Processing Influences Conflict Adaptation One way emotions arise is through individuals' subjective experience and evaluation of events [?, ?]. Accordingly, integral negative affect from conflict processing may stem from subjective experience and evaluation of the conflict itself. While researchers cannot directly manipulate integral negative affect during conflict processing, they can examine its influence through individuals' reported subjective experiences. Specifically, studies have used masked priming paradigms to induce conflict, where briefly presented and nearly invisible primes could be congruent or incongruent with target stimuli, creating objective non-conflict and conflict trials. After responding to target arrows, participants reported their subjective perception of whether conflict information was present, creating subjective conflict or non-conflict trials independent of objective conflict. Results showed that conflict adaptation was significant only when participants subjectively reported experiencing conflict [?, ?, ?], indicating that subjective experience during conflict processing plays a critical role, while objective conflict processing itself is not a necessary condition for eliciting adaptation. Following this, Fröber et al. (2017) combined behavioral and EEG methods to further investigate how subjective emotional experiences during conflict processing influence adaptation.

Using a Simon task to induce conflict, participants rated their emotional experience after each trial on a scale from unpleasant to pleasant. Conflict adaptation analyses considered both previous trial congruency and accompanying subjective emotional experience (pleasant vs. unpleasant). Results showed that conflict adaptation was significant only when previous trials were rated as emotionally negative. This finding was corroborated at the EEG level: when previous trials were rated positive, the lateralized readiness potential (LRP) amplitude was larger for current incongruent than congruent trials; however, when previous trials were rated negative, LRP amplitudes did not differ between current congruent and incongruent trials. These studies demonstrate that subjective emotional experiences based on conflict processing can facilitate conflict adaptation, with their positive effects contingent on conscious awareness of conflict information and/or integral negative affect.

4.1.3 Potential Influence of Emotion Regulation in Conflict Adaptation More broadly, emotion is a response to cognitive processing \cite{刘烨等，2009}. Conflict adaptation and emotion regulation are therefore similar in essence, reflecting individuals' real-time adjustments to processed information to achieve a comfortable and pleasant subjective state while adapting to changing external contexts [?, ?, ?]. The difference lies in their regulatory targets: conflict information for conflict adaptation, emotional information for emotion regulation. When conflict processing triggers brief negative affective states, individuals initiate emotion regulation [?, ?]. From this perspective, conflict adaptation—from monitoring in previous trials to regulation in current trials—can also be viewed as an emotion regulation process. Researchers have further proposed that conflict adaptation can be understood as involving dynamic monitoring of negative affect [?, ?, ?]. This hypothesis not only reflects the intrinsic link between negative affect and cognitive conflict processing but also provides a novel integrated perspective for understanding integral negative affect' s role in conflict adaptation—by exploring how emotion regulation functions during conflict or similar high-load cognitive processing.

Similar to conflict processing, error processing also automatically evokes negative affect [?, ?]. Based on this, Dignath et al. (2019) examined emotion regulation's influence on error processing in a physiological study, finding that emotion regulation participates in error processing. Other researchers have used EEG to investigate how regulating negative affect generated during error processing influences error processing itself. Results showed that down-regulating negative affect impacted response monitoring systems, impairing task performance, an effect reflected in reduced error-related negativity (ERN) amplitudes [?, ?]. These findings provide objective evidence for integral negative affect regulation' s involvement in high-load cognitive processing and show that such regulation can 反过来 influence cognitive (error) task performance. Additionally, research has explored links between emotion regulation and conflict processing. Moser et al. (2010) found that emotion regulation (cognitive reappraisal) reduced conflict effects, indicating that emotion regulation facilitates conflict processing at the trial level. Regarding inter-trial dynamics (conflict adaptation), correlational studies show that conflict adaptation effects negatively correlate with Emotion Regulation Questionnaire (ERQ; [?, ?]) scores [?, ?], suggesting that individuals skilled at cognitive reappraisal show lower conflict adaptation, indirectly indicating emotion regulation' s influence on adaptation. Nevertheless, current research only provides preliminary evidence for the hypothesis that conflict adaptation can be viewed as an emotion regulation process [?, ?], with challenges remaining in designing appropriate experimental paradigms. Traditional emotion regulation requires instructing participants to use strategies like cognitive reappraisal or expressive suppression to regulate negative (or positive) emotions induced by sad (or pleasant) films or music [?, ?]—relatively slow processes. Conversely, exploring negative affect' s role in conflict adaptation from an emotion regulation perspective requires integrating emotion regulation into rapidly processed conflict tasks.

4.2 Underlying Mechanisms of Integral Negative Affect in Eliciting Conflict Adaptation

According to the conflict-monitoring model [?, ?], conflict information plays a crucial role in conflict monitoring and regulation (i.e., adaptation). Building on this model, Dignath et al. (2020) proposed the affective-signaling hypothesis (Figure 1B), emphasizing the important role of integral negative affect automatically generated during conflict processing. According to this hypothesis, integral negative affect can elicit conflict adaptation either during the monitoring stage via a "negative affect → monitoring" pathway [?, ?] or directly during the regulation stage via a "negative affect → regulation" pathway. From the separation perspective, conflict information is the primary source triggering cognitive control, with negative affect playing only an indirect intermediate role. From the integration perspective, however, conflict information together with integral negative affect jointly activate cognitive control, more effectively controlling and resolving conflict (Figure 1C). Yet only when individuals consciously perceive conflict information and/or accompanying integral negative affect can this goal-relevant information be transmitted and integrated in dACC [?, ?], more effectively activating cognitive control and promoting the adaptive loop from conflict monitoring to regulation. Whether through monitoring or regulation pathways, integral negative affect accompanying target conflict makes conflict stimuli more salient, inherently promoting goal-directed behavior to more effectively resolve conflict and reduce its recurrence and/or associated integral negative affect [?, ?].

5.1 Summary

This paper has examined negative affect' s role in conflict adaptation from both separation and integration perspectives, deepening our understanding of this issue. From the separation perspective, negative affect manipulated outside conflict operates as an independent variable, influencing adaptation through the emotional processing system or individual motivational/arousal levels (Figure 1A). From the integration perspective, integral negative affect generated within conflict is highly integrated with conflict processing, functioning similarly to conflict information and directly eliciting conflict adaptation (Figures 1B, 1C).

5.2 Future Directions

The discovery that conflict processing automatically generates negative affect has led increasing researchers to focus on how integral negative affect' s generation and regulation during conflict processing influences adaptation. While this topic provides a novel framework for exploring integration processes and mechanisms between cognitive and emotional systems, two key issues require further investigation.

5.2.1 Neural Mechanisms Underlying Integral Negative Affect' s Influence on Conflict Adaptation

Research has established associations between negative affect and conflict processing across behavioral performance, physiological responses, and neural representations, providing preliminary empirical evidence for integral negative affect's facilitative effect on conflict adaptation at behavioral and EEG levels. However, due to the complexity of (negative) emotional processing and its involvement of multiple components, the underlying mechanisms remain unclear. Future research could employ a "two-stage" paradigm for deeper investigation. In Stage 1, establish associations between integral negative affect and specific conflicts: for example, in a color Stroop task, bind only "red" and "blue" Stroop stimuli with negative pictures while binding "yellow" and "green" stimuli with neutral pictures. In Stage 2, dissolve these bindings and present only color Stroop stimuli. By comparing conflict adaptation across different color Stroop stimuli in Stage 2, researchers can examine how integral negative affect from conflict processing (Stage 1) influences adaptation. Building on the affective-signaling hypothesis [?, ?] and the Dual Mechanisms of Control (DMC) model [?, ?], future studies could map the two pathways of negative affect' s influence on adaptation ("negative affect → monitoring" vs. "negative affect → regulation") onto the DMC model' s two control modes (reactive vs. proactive). Using fMRI and brain network analysis, researchers could investigate how cognitive control networks (dACC and DLPFC) communicate and integrate with emotion processing regions (insula and amygdala), thereby revealing the neural mechanisms through which integral negative affect influences conflict adaptation.

5.2.2 The Relationship Between Emotion Regulation and Cognitive Control

Conflict adaptation is a key index of cognitive control that shares similarities with emotion regulation. Both involve dynamic adjustment of information processing and engage cognitive control systems. Exploring the association between emotion regulation and conflict adaptation can reveal shared underlying mechanisms and address whether conflict information and negative affect regulation share a unified cognitive control system or rely on independent systems, providing an effective research approach for understanding cognitive-emotional integration. To investigate these questions, future research could use fMRI with Representational Similarity Analysis (RSA) to decode similarities in brain activation patterns of cognitive control during conflict adaptation and emotion regulation, revealing how cognitive control mechanisms involved in conflict adaptation contribute to emotion regulation and laying a neural foundation for intervention studies.

Furthermore, if conflict adaptation and emotion regulation share a unified cognitive control system, a practically significant question is whether cognitive control training based on conflict adaptation can enhance emotion regulation ability. Future studies could address this through behavioral task training and neural intervention protocols. Specifically, a three-stage paradigm ("emotion regulation → conflict task (cognitive control) training → emotion regulation") with between-subjects designs could examine changes in emotion regulation at subjective, physiological, and neural levels (focusing on basal ganglia and cognitive control networks including dACC and DLPFC) before and after conflict task training [?, ?, ?]. Additionally, transcranial direct current stimulation (tDCS) could be used to directly modulate DLPFC activity in independent participant groups, more directly examining how cognitive control training and intervention influence emotion regulation capacity.

Conversely, can emotion regulation training enhance cognitive control? Future research could approach this from two angles. First, using neurofeedback technology, train participants for one week (1 hour per week) on classic emotion regulation tasks (employing the well-established cognitive reappraisal strategy [?, ?]) and compare behavioral and brain activity changes during cognitive control tasks before and after training. Second, use the ecologically valid method of mindfulness to train individuals to regulate emotional events in daily life, then compare behavioral and neural changes during cognitive control tasks pre- and post-training.

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Note: Figure translations are in progress. See original paper for figures.