Conflict Monitoring and the Affective Signaling Hypothesis – an Integrative Review

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Abstract

Conflict monitoring theory proposes that conflict between incompatible responses is registered by a dedicated monitoring system and that this conflict signal triggers changes of attentional filters and adapts control processes according to current task demands. Extending the conflict monitoring theory, it has been suggested that conflict elicits a negative affective reaction, and that it is this *affective signal* that is monitored, and then triggers control adaptation. This review article summarizes research on this signaling function of affect for cognitive control. First, we provide an overview of the conflict monitoring theory, discuss neurophysiological and behavioral markers of monitoring and control adaptation, and introduce the affective signaling hypothesis. In a second part, we review relevant studies that address questions (i) whether conflict elicits negative affect, (ii) whether negative affect is monitored, (iii) and whether affect modulates control. In sum, the reviewed literature supports the claim that conflict and errors trigger negative affect and provided some support for the claim that affect modulates control. However, studies on monitoring of negative affect and the influence of phasic affect on control are ambiguous. Based on these findings, in a third part, we critically reassess the affective signaling hypothesis, discuss relevant challenges to this account, and suggest future research strategies.

(204 words)

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Dual-system frameworks in psychology often portrayed affective processes as opposing forces to willful behavior: During goal pursuit, people must often resist distracting behavioral impulses associated with affective states (Metcalfe & Mischel, 1999; Muraven & Baumeister, 2000; Strack & Deutsch, 2004). However, more recent research has highlighted a functional interaction between cognitive control and affect (Pessoa, 2008; Goschke & Bolte, 2014). For instance, affective states (i.e., valence and arousal, see Barrett & Russell, 1999) convey important information about our inner life and have an important signaling function for many cognitive operations (Damasio, 1996; Frijda, 1988; Oatley & Johnson-Laird, 1987). This article is concerned with the particular signaling function of affect for cognitive control.

Research on cognitive control described a dedicated neurocognitive system that monitors the planning, initiation, and execution of actions. According to the conflict monitoring theory, performance monitoring serves to inform and change future behavior (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Although initially envisaged as a cognitive theory, recent proposals suggested that conflict between mutually exclusive responses triggers a negative affective reaction and that it is this affective response to conflict which is registered by the performance monitoring system. Upon registration, the affective reaction triggers adaptations of attention and performance that aim to attenuate future conflict (Botvinick, 2007; Dreisbach & Fischer, 2015; Inzlicht, Bartholow, & Hirsh, 2015; van Steenbergen, 2015). In the following we refer to this set of theoretical positions as the *affective signaling hypothesis.* In short, it assumes a bidirectional link between affect and control: Affect is not only the output of control-related processes (i.e., conflict elicits negative affect); it can also serve as input for control-related processes (i.e., negative affect as a learning signal).

Interestingly, the affective signaling hypothesis suggests a novel perspective on the interaction between affect and cognitive control. Affect can be understood as the fuel and driving force of control operations whereas (cognitive) control operations can be understood in a more general framework of affect-regulation. This potential to reconcile cognitive and affective operations into a common mechanism makes the affective signaling hypothesis particularly attractive.

Research on the interplay between affect and cognitive control expanded rapidly in the last decade (cf. Okon-Singer, Hendler, Pessoa, & Shackman, 2015)[1]. Regarding the affective signaling hypothesis, previous work focused on neuroanatomical (Shackman et al., 2011), psychophysiological (Saunders, Lin, Milyavskaya, & Inzlicht, 2017) and behavioral (Dreisbach & Fischer, 2012, 2015, 2016) aspects.The present article complements previous work by providing a comprehensive review of relevant research with the aim to evaluate the currently available evidence related to the affective signaling hypothesis. Following recent theorizing (Dreisbach & Fischer, 2012; van Steenbergen, 2015), the current article integrates the literature from different domains according to the particular theoretical perspective of the conflict monitoring theory (for a different view, see Notebaert & Verguts, 2008). Conflict monitoring offers a detailed and mechanistic description of cognitive control, which allows a close matching of affective processes on control mechanisms. Furthermore, conflict monitoring theory explains response conflict and error processing in a unitary model. This allows an integration of empirical work that focused either on conflict or errors.

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[1] A Web of Science© search using the terms "TS=((cognitive control) AND (affect* OR emotion*)) AND SU=(Psychology OR Neurosciences & Neurology OR Behavioral Sciences) AND PY=(2000-2018)" showed that the number of publications on "cognitive control and affect" increased from 279 in the year 2000 to 2130 in the year 2018.

The structure of the argument in this article includes three parts. The first section introduces the conflict monitoring theory with respect to its two central components – performance monitoring and control adaptation – and derives a process model of the affective signaling hypothesis within this model. In the second part, we review evidence relevant to the affective signaling hypothesis. Three lines of research are reviewed: (i) behavioral and physiological evidence showing that conflict and errors elicit negative affect; (ii) neurophysiological evidence showing that correlational and experimental manipulations of affect influence monitoring of conflict and errors; (iii) behavioral evidence showing that correlational and experimental manipulations of affect influence adaptation of control to conflict and errors. The third part provides a critical discussion of the affective signaling idea and suggestions for future research.

1. Conflict monitoring theory

Conflict between temporally co-activated, but mutually exclusive actions is a fundamental challenge for action control, and it has been suggested that control mechanisms are needed to prevent and/or resolve conflict (see e.g., Allport, 1987; Botvinick et al., 2001; Miller & Cohen, 2001; Norman & Shallice, 1986). An influential model that accounts for such control mechanisms is the conflict monitoring theory. Here, conflict is registered and used to change control settings. Importantly, the conflict monitoring theory views errors as special case of conflict. While conflict in correct trials should be highest before response execution (i.e. before the correct response is selected), conflict in trials with incorrect responses should be highest after response execution, because of the conflict between the incorrect response and a tendency to correct the produced response (cf. Yeung, Botvinick, & Cohen, 2004).

Conflict monitoring entails two components: (1) a monitoring component that evaluates the degree of conflict and (2) a control adaptation component that adjusts attentional filters to the current task demands. Concerning neural implementation, monitoring has been associated to the dorsal regions of the anterior cingulate cortex (dACC) (Botvinick, Nystrom, Fissel, Carter, & Cohen, 1999; Carter et al., 1998), while control adaptation has been linked to activity in the dorsolateral prefrontal cortex (DLPFC), which is associated with a sharpening of relevant task representations (Kerns et al., 2004). These two control components complement each other and form a control loop: The conflict signal triggers control adaptation by means of a learning signal that specifies a need for changes in attention. These changes in attention, in turn, lead to a subsequent reduction of conflict. In what follows, we present a selective review of evidence for both components.

1.1 Performance monitoring

One way to probe the monitoring component is the usage of scalp-recorded electrophysiological potentials. For instance, the N2 component has been described as a negative deflection in the EEG that peaks around 250 ms after stimulus onset and is larger after the presentation of a conflicting stimuli (Kopp, Rist, & Mattler, 1996; Yeung, Botvinick, & Cohen, 2004; see also Liotti, Woldorff, Perez, & Mayberg, 2000 for the Stroop task). Furthermore, errors are reflected in the EEG by the error-related negativity (ERN) (cf. Yeung, et al., 2004; for alternative accounts, see Alexander & Brown, 2010; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Holroyd & Coles, 2002; Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001). The ERN peaks around 100 ms after an incorrect response (Falkenstein, 1990; Gehring, 1990; see Gehring, Liu, Orr, & Carp, 2012 for a review); it is sensitive to the frequency of errors (Holroyd & Coles, 2002), the motivational significance (Hajcak, Moser, Yeung, & Simons, 2005) and the type of error (Bernstein, Scheffers, & Coles, 1995; Maier & Steinhauser, 2013). In line with the view that errors reflect a special case of conflict, dipole source location and fMRI studies identified the dACC and the premotor supplementary areas as the neural generators of the N2 and the ERN response (Carter et al., 1998; Dehaene, Posner, & Tucker, 1994; Holroyd et al., 2004; Keil, Weisz, Paul-Jordanov, & Wienbruch, 2010; Miltner et al., 2003; Ridderinkhoff, Ullsperger, Crone, & Nieuwenhuis, 2004).

1.2 Control adaptation

Studies on performance monitoring are complemented by behavioral and neuroimaging studies on control adaptation. Conflict adaptation is indexed by the *sequential congruency effect,* which describes a modulation of the congruency effect as a function of the level of congruency of the preceding trial. In particular, congruency effects in the current trial N are reduced after incongruent (relative to congruent) trials in N-1. The sequential congruency effect has been observed in a variety of response interference paradigms (flanker: Gratton, Coles, & Donchin, 1992; Simon: Fischer, Plessow, Kunde, & Kiesel, 2010; Stroop: Kerns et al., 2004; priming-tasks: Kunde & Wühr, 2006; Go/NoGo task: Smith, Smith, Provost, & Heathcote, 2010; task switching: Kiesel, Wendt, & Peters, 2007).

Studies showed that sequential congruency effects result from enhanced perceptual processing of the relevant stimulus dimension (e.g., Egner & Hirsch, 2005a; Nigbur, Schneider, Sommer, Dimigen, & Stürmer, 2015) and weakening of automatic response activation by the irrelevant stimulus dimension (Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002; Stürmer, Redlich, Irlbacher, & Brandt, 2007). Accordingly, the sequential congruency effect corresponds to an adjustment of attentional filtering efficacy and indexes control adaption: When an incongruent stimulus is encountered, conflict is detected and triggers an up-regulation of attentional focus that facilitates behavioral performance.

1.3 The control loop: From performance monitoring to control adaptation

In theory, the idea that monitoring informs control adaptation has two implications: First, the monitoring signal provides a means to gauge the need for control. Thus, the strength of conflict should scale with the magnitude of control adaption. This prediction is supported by studies showing that increased monitoring of conflict in the preceding trial (as indicated by the N2) is accompanied by an increased magnitude of sequential congruency effect (Forster, Carter, Cohen, & Cho, 2010; Wendt, Kiesel, Gehringswald, Purmann, & Fischer, 2014; but see Egner, Jamieson, & Gruzelier, 2005). Furthermore, conflict-related activity in the dACC during the preceding trial predicts the size of the sequential congruency effect in the subsequent trial (Kerns et al., 2004), and lesions of the dACC impair the sequential congruency effect (di Pellegrino, Ciaramelli, & Làdavas, 2007; Tolomeo et al., 2016; but see Fellows & Farah, 2005; Vendrell, Junqué, Pujol, Jurado, Molet, & Grafman, 1995). The second assumption holds that monitoring of conflict is not identical with control adaptation in terms of neural localization. This prediction is supported by studies showing that the size of the sequential congruency effect correlates with activity in the DLPFC but not in the dACC (Kerns et al., 2004; Egner & Hirsch, 2005b). Further support comes from virtual lesion studies showing that transcranial direct current stimulation to the dACC and SMA (supplementary motor area) increased error monitoring (as indexed by the ERN, Reinhart & Woodmann, 2014), while stimulation of the DLPFC enhanced the magnitude of the sequential congruency effect (Gbadeyan, McMahon, Steinhauser, & Meinzer, 2016).

1.4 An affective interpretation of conflict - The affective signaling hypothesis

The original version of conflict monitoring was introduced as a theory of cognitive control. However, authors endorsed the idea that conflict and error monitoring are based on affective processes (e.g., Luu, Collins, & Tucker, 2000). This inference is motivated by neurophysiological studies showing that the dACC is not exclusively activated by conflict and errors, but also serves as a central hub for information processing related to emotions and in particular negative affect (Papez, 1937; Kober et al., 2008), pain (Rainville, Duncan, Price, Carrier, & Bushnell, 1997), and social distress (Eisenberger, Lieberman, & Williams, 2003; for a meta-analysis, see Shackman et al., 2011). Furthermore, evidence from local field potentials during intracranial recording showed selective coupling between dACC and the amygdala, suggesting that the dACC is part of a broader affective network in the brain (Pourtois et al., 2010; see also Kunishio & Haber, 1994). Lesions of the dACC also cause severe deficits in the recognition of negative emotions (Tolomeo et al., 2016) and in motivated action, despite intact motoric abilities (akinetic mutism; see Németh, Hegedüs, & Molnâr, 1988). Together, this body of evidence suggests that neuronal correlates of performance monitoring and affective processing overlap substantially.

In line with an affective interpretation of dACC activity, it has been suggested that the ERN reflects an affective response to errors (Pailing, Segalowitz, Dywan, & Davies, 2002; Luu & Peterson, 2004; Yeung et al., 2004). Gehring and Willoughby (2002) proposed that “the ERN might reflect an appraisal of the motivational or affective impact of the error rather than a computation related to detecting the error or response conflict” (p. 2281). The hypothesis that the monitoring system registers affective reactions to conflict and error was supported by studies showing that both are evaluated negatively (e.g., Aarts, De Houwer, & Pourtois, 2012; Dreisbach & Fischer, 2012; Hajcak & Foti, 2008). Furthermore, other research found that experimentally induced positive affect reduced control adaptation (indexed by the sequential congruency effect), presumably because it weakened the negative affective signal driving control adaptation (e.g., van Steenbergen, Band, & Hommel, 2009).

Based on these observations, researchers proposed an affective-control framework that ascribes a central role of conflict- or error-triggered affect for control (e.g., the *´conflicts as aversive signals framework´,* Dreisbach & Fischer, 2015; see also Inzlicht et al., 2015; Saunders et al., 2017; van Steenbergen, 2015). For instance, it has been suggested that "cognitive control […] is dependent on emotion" (Inzlicht et al., 2015, p. 126), and that "conflict adaptation […] might actually represent an instantiation of affect regulation" (Dreisbach & Fischer, 2015, p. 256). More specifically, these accounts assumed that conflict or errors elicit an affective reaction (we will refer to this assumption as the conflict ▶ affect link). Subsequently, performance monitoring does not register conflicts and errors alone, but importantly, it detects also the affective reaction to these events (we refer to this assumption as the affect ▶ monitoring link). And finally, this affective response to conflict and errors, rather than conflict and errors per se, drives changes in control adaptation: An affective learning signal causes an updating of relevant task representations and is a direct function of the registered affective response (we refer to this assumption as the affect ▶ control link). The last claim assumes that negative affect elicited through conflict/errors is not only a byproduct of conflict processing but rather causal for control adaptation. We will refer to this set of propositions as the *affective signaling hypothesis* (see Figure 1 for an illustration). In the next part of this article will review evidence for each of these claims.

>>>FIGURE 1<<<

2. Evidence for the affective signaling hypothesis

The following literature review is structured into three sections. In the first section, we review evidence for the assumption that conflict or errors trigger an affective response (i.e., the conflict ▶ affect link). Here, studies are discussed that probed participants' explicit, implicit, and physiological valuation of conflict and errors. In the second section, we review evidence for the assumption that the monitoring process is influenced by affective states (i.e., the affect ▶ monitoring link). This section reviews studies that investigated the effects of affective states on ERN or N2 responses. In the third section, we review evidence for the assumption that control adaptation is triggered by negative affective states (i.e., the affect ▶ control link). This section describes studies that investigated the effects of affective states on the sequential congruency effect.

2.1 Inclusion criterion for the literature review.

Before we begin reviewing empirical evidence, we first narrow down the scope of the reviewed research.

2.1.1 Selection of conflict tasks.

Because the notion of conflict is central to conflict monitoring and affective signaling, only studies that employed response interference tasks were considered (i.e., flanker, Stroop, Simon, the grasp compatibility effect , Go/NoGo tasks, stop-signal tasks, and task switching[2]). Other paradigms that measure further aspects of cognitive control like working memory updating and maintenance (e.g., task-rule switching, the AX-CPT task, span tasks, or N-back tasks) are not reviewed here. We also did not include studies on the emotional interference Stroop task, because affective information is part of the relevant response set (Etkin, Egner, Peraza, Kandel, & Hirsch,

[2] Only studies that used bi-valent stimuli which allow for response-congruency effects were included. Typically, response-congruency effects are larger on task alternation compared to task repetition trials and therefore contribute significantly to switch costs (Goschke, 2000).

2006) and we also excluded studies on the ‘typical’ emotional Stroop task, because this effect has been attributed to an unspecific slowing (Algom, Chajut, & Lev, 2004).

2.1.2 Selection of dependent variables.

All included task protocols elicit response conflict that can be measured with the N2 or ERN as markers of performance monitoring and results in compensatory changes in attention that can be measured with the sequential congruency effect as a marker of control adaptation. The Feedback-related negativity (FRN) is not considered, because it is beyond the scope of the conflict monitoring theory. Post-error slowing is not discussed because its relation to monitoring and cognitive control is unclear (for discussions, see Danielmeyer & Ullsperger, 2011; Steinhauser, Ernst, & Ibald, 2017). For measures of affect, we considered both explicit (e.g., ratings) and implicit (e.g., affective priming) behavioral measures and physiological markers of valence and arousal (see Table 1 for details).

2.1.3 Selection of affective manipulations.

We define ‘affect’ as a psychophysiological construct that is characterized by (i) the pleasantness or hedonic tone of an episode (valence), and (ii) a potential for (physiological) mobilization or energization (arousal) (Barrett & Russell, 1999). Affective states differ in duration and can range from brief affective sensations (phasic) to relatively long-lasting moods (tonic). We will refer to manipulations that change affect on a trial-by-trial basis as *phasic affect,* because these affective reactions are likely to decay in the order of seconds (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Codispoti, Bradley, & Lang, 2001). In contrast, we refer to manipulations that induce more enduring affective states as *tonic affect*.

Regarding phasic manipulations of affect, studies were considered in which presentations of affective stimuli were *not* contingent upon behavioral performance. If studies compared performance contingent and non-contingent affect presentation across groups, we considered only data of the performance non-contingent group (e.g., Braem, et al., 2013; Yamaguchi & Nishimira, 2018). The distinction between affective states that are contingent or independent from behavioral performance is important, because research has shown that stimuli acquire reinforcing properties when they signal correct performance, which strengthens the active attentional set (for a discussion see Chelazzi et al., 2013). In particular, it has been argued that control adaptation in terms of the sequential congruency effect is increased by presentations of performance-contingent affective stimuli (see Braem et al., 2012; Braem et al., 2015; Yang, & Pourois, 2018).

Affective states are also closely linked to motivational tendencies of approach and avoidance. While positive affect was typically linked to approach motivation, and negative affect to avoidance (Elliot, Eder, & Harmon-Jones, 2013), one should be cautious in inferring motivational states from affective states, because unpleasant states can also evoke motivations to approach (e.g., aggressive behavior, see Berkowitz & Harmon-Jones, 2004; Carver & Harmon-Jones, 2009) and behavioral approach could subserve prevention goals (Higgins, 1997).

2.1.4 Literature search strategy.

We retrieved studies published in peer-review journals in English by conducting database searches through Web of Science© and Google Scholar© (search period 2000-2018, for the research areas Psychology, Behavioral Sciences and Neuroscience, and Neurology) separately for each of the three sections described above. In addition, we carefully examined the reference sections of qualifying articles and previous literature reviews for citations and searches on the names of frequently occurring authors. When available, we will refer to meta-analysis or review articles of specific research areas. For brevity, this literature will not be reviewed again (but see Tables 1-3).

2.2 Conflict triggers affect – the conflict ▶ affect link

What are the downstream consequences of conflict? A direct prediction of the affective signaling hypothesis is that conflict and errors elicit negative affect. Therefore, evidence is reviewed that manipulated conflict/errors experimentally and examined affective reactions (for an overview see Table 1).

2.2.1 Conflict is aversive.

Studies that used explicit measures of affect asked participants to report their subjective feelings during conflict and non-conflict trials (Stroop: Morsella, Gray, Krieger, & Bargh, 2009; Simon: Fröber, Stürmer, Frömer, & Dreisbach, 2017; grasp-compatibility: Regenberg, Häfner, & Semin, 2012, Exp. 2; Errors: Spunt, Lieberman, Cohen, & Eisenberger, 2012). Implicit measures of affect using behavioral indices of affect provided converging evidence for an affective evaluation of conflict using different measures of affect. In the affective priming procedure (Fazio, Sanbonmatsu, Powell, & Kardes, 1986), a prime stimulus (e.g., a Stroop color word) is presented before a clearly positive or negative target stimulus (e.g., a picture). Participants are instructed to categorize the valence of the target as quickly and accurately as possible. Several studies found faster responses for negative targets following an incongruent compared to a congruent prime and faster response for positive targets following an congruent compared to a incongruent prime (grasp-compatibility effect: Brouillet, Ferrier, Grosselin, Brouillet, 2011; Stroop: Dreisbach & Fischer, 2012; Pan et al., 2016, Exp. 1; flanker: Schouppe et al., 2015, Exp. 1; Ivanchei et al., 2018). The affective priming paradigm also provided evidence for negative affective responses following errors (Go/NoGo task: Aarts, De Houwer, & Pourtois, 2012, 2013; De Saedeleer & Pourtois, 2016). Further support for a priming of negative affect by conflict comes from an EEG study which observed an increased late positive potential for negative pictures following flanker conflict, suggesting enhanced processing of negative pictures after conflict (Ligeza & Wyczesany, 2017; but see Steinhauser, Flaisch, Meinzer, & Schupp, 2016).

Another task for an indirect measurement of affective reactions is the affect misattribution procedure (AMP; Payne, Cheng, Govorun, & Stewart, 2005). In this task, participants are presented with a prime stimulus (e.g., a Stroop color-word) that is followed by a neutral target stimulus (e.g., a Chinese character). Participants should evaluate the neutral target by pressing a positive or a negative response key. Studies showed that the evaluations of neutral targets were more negative following a conflict prime relative to a non-conflict prime stimulus (Stroop: Fritz & Dreisbach, 2013, 2015; Damen, Strick, Taris, & Aarts, 2018; grasp-compatibility: Regenberg et al., 2012, Exp.1; flanker: Goller, Khalid, & Ansorge, 2017; Martiny-Huenger, Gollwitzer, & Oettingen, 2014; task switching: Vermeylen, Braem, & Notebaert, 2019; Go/NoGo task: Buttaccio & Hahn, 2010; Doallo et al., 2012; Fenske, Raymond, Kessler, Westoby, & Tipper, 2005; Ferrey, Frischen, & Fenske, 2012; Frischen, Ferrey, Burt, Pistchik, & Fenske, 2012; Kiss, Raymond, Westoby, Nobre, & Eimer, 2008; errors: Chetverikov et al., 2017).

Physiological evidence for a negative evaluation of conflicts and errors comes from electromyographic recordings of the *zygomaticus major* (the ‘smiling muscle’ involved in positive affect). One study observed increased activity for congruent compared to incongruent trials in a combined Simon/grasp-compatibility task (Cannon, Hayes, & Tipper, 2010). Furthermore, recordings of the *corrugator supercilii* (the 'frowning' muscle' involved in negative affect) during a Go/NoGo task showed increased activity following conflict (Schacht, Nigbur, & Sommer, 2009; Lindström, Mattsson-Mårn, Golkar, & Olsson, 2013) and errors (Elkins-Brown, Saunders, & Inzlicht, 2016; Elkins-Brown, Saunders, He, & Inzlicht, 2017, Exp. 2; Lindström, Mattson-Marn, Golkar, & Olsson, 2013).

Further evidence for the negative evaluation of conflict comes from a study that used repetition suppression (a technique that is based on the observation that repeated activation of the same brain areas reduces activation of the neural system) and found that dACC responses to negative pictures were reduced following conflict compared to non-conflicting trials, suggesting that conflict already triggered the same neural representation as the negative pictures (Braem, King, Korb, Krebs, Notebaert, & Egner, 2017).

Several studies also showed that conflict-related stimuli trigger behavioral avoidance (Dignath & Eder, 2015; Hatukai & Algom, 2017; Schouppe, De Houwer, Ridderinkhof, & Notebaert, 2012). Similarly, errors (Hochman, Milman, & Tal, 2017) and tasks associated with conflict and errors facilitate avoidance behavior (Botvinick & Rosen, 2009; Botvinick, Huffstetler, & McGuire, 2009; Desender, Buc Calderon, van Opstal, & van den Bussche, 2017; Dignath, Kiesel, & Eder, 2015; Dunn, Gasper, & Risko, 2018; Gold et al., 2015; Kool, McGuire, Rosen, & Botvinick, 2010; Kool, McGuire, Wang, & Botvinick, 2013; McGuire & Botvinick, 2010; Schouppe, De Houwer, Ridderinkhof, & Notebaert, 2014; Sayalı & Badre, 2019). In addition to studies showing that conflict triggers negative affect, we now review studies on the relationship between conflict/errors and arousal.

2.2.2 Conflict is arousing.

Evidence for an arousing effect of conflict comes from physiological studies. Skin conductance responses increase during conflict (Stroop: Kobayashi, Yoshino, Takahashi, & Nomura, 2007; Naccache et al., 2005, Exp. 9; Renaud & Blondin, 1997; Waid & Orne, 1982; but see Schacht, Nigbur, & Sommer, 2009; Schacht, Dimigen, & Sommer, 2010 for the reverse pattern in the Go/NoGo task) and after errors (Hajcak, McDonald, & Simons, 2003, 2004). Furthermore, many studies reported increased pupil diameter in incongruent compared to congruent Stroop task trials (for a review see van der Wel & van Steenbergen, 2018). Studies also found a decelerated heart beat in incongruent trials (flanker: Fiehler, Ullsperger, Grigutsch, & von Cramon, 2004; Kuipers et al., 2017; Go/NoGo: Hajcak et al., 2003; van der Veen, van der Molen, & Jennings, 2000) and after errors (Hajcak et al., 2003; Fiehler et al., 2004). Conflict (Kuipers et al., 2017) and errors (Spruit, Wilderjans, & van Steenbergen, 2018) also increase sympathetic beta-adrenergic activity of the heart. Some studies found that the protective-defensive startle reflex is potentiated after errors (Hajcak & Foti, 2008; Riesel, Weinberg, Moran, & Hajcak, 2013). However, this finding is inconsistent with studies reporting a *reduced* startle reflex potentiation in conflict trials (Go/NoGo task[3]: Schacht et al., 2009; Schacht et al., 2010; Schupp, Lutzenberger, Rau, & Birbaumer, 1994).

2.3 Conflict is registered as an affective signal – the affect ▶ monitoring link

According to the affective signaling hypothesis, the affective reaction to conflict is registered by a monitoring system. This raises the possibility that affective states systematically alter the monitoring of conflicts and errors. In this section, we provide an overview of research that directly tested this assumption. First, correlational

[3] It should be noted that the Go/NoGo task confounds no-conflict/conflict with action/no-action which could provide an alternative explanation for startle modulation here.

evidence is reviewed testing the prediction that monitoring of conflict-triggered negative affect should be increased for individuals who experience more and stronger negative affect. This line of argumentation is complemented by studies that test the prediction that experimental induction of negative affect should boost the monitored affective consequences of conflict and errors. Table 2 summarizes this literature.

2.3.1 Correlational evidence for the affect ▶ monitoring link.

The most compelling evidence for a relationship between affect and monitoring comes from studies investigating interindividual differences in electrophysiological responses to errors and conflict. Numerous reviews and meta-analyses overlooking more than 50 studies reached the conclusion that chronic dispositions to negative affect are associated with enhanced processing of errors and conflict. Specifically, trait negative affect, avoidance dispositions, depression, general anxiety, symptoms of worry, and social distress in both clinical and non-clinical populations correlate positively with N2/N450 and ERN amplitudes (Cavanagh & Shackman, 2015; Endrass & Ullsperger, 2014; Koban & Pourtois, 2014; Meyer, 2017; Moser, Moran, Schroder, Donnellan, & Yeung, 2013; Weinberg, Dieterich & Riesel, 2015).

However, the conclusions drawn from these relationships varied considerably. Koban and Pourtois (2014) suggested that errors (but not conflict) activate brain areas involved in affective processing outside the dACC (e.g., the amygdala). Cavanagh and Shackman (2015) proposed that negative affect and conflict are integrated within the dACC to guide adjustments of cognitive control. Moser et al. (2013) hypothesized that the increased ERN in anxiety reflects the distracting effects of worry. Particularly the latter idea illustrates a general problem of these correlative studies. It is unclear whether it is affect that directly has an impact on monitoring or whether it is a third variable such as the susceptibility to rumination that mediates the effect of affect on monitoring (Moser et al., 2013). This ambiguity limits the utility of correlative evidence for a strong evaluation of the affective signaling hypothesis. However, if a relationship between negative affect and enhanced monitoring of errors and conflicts would exist, one would expect analogous results for studies that manipulate affective states experimentally.

2.3.2 Experimental evidence for the affect ▶ monitoring link.

The majority of experimental studies manipulated mood states using induction methods such as autobiographical scripts and imagery (Larson, Gray, Clayson, Jones, & Kirwan, 2013; Nixon, Liddle, Nixon, & Liotti, 2013; Paul, Walentowska, Bakic, Dondaine, & Pourtois, 2017); emotional movies (Olvet & Hajcak, 2011; Wang, Yang, & Wang, 2014); encouraging feedback (Clayson, Clawson, & Larson, 2011; Wiswede, Münte, & Rüsseler, 2009); facial feedback (Wiswede, Münte, Krämer, & Rüsseler, 2009); social exclusion (Otten & Jonas, 2014; Themanson, Ball, Khatcherian, & Rosen, 2014); in-vivo confrontation with spiders (Moser, Hajcak, & Simons, 2005); affective touch (Saunders, Riesel, Klawohn, & Inzlicht, 2018); or induction of helplessness (Pfabigan et al., 2013).

Of those studies that analyzed the ERN, only five of them found a valence effect in the expected direction, that is, a larger ERN for negative than for positive or neutral valence (Wiswede, Münte, Rüsseler, 2009; Pfabigan et al., 2013), a smaller ERN for positive than for neutral valence (Wiswede, Münte, Krämer, & Rüsseler, 2009; see also Hobson, Saunders, Al-Khindi, & Inzlicht, 2014), or a smaller ERN when negative affective states were successfully suppressed (Wang, Yang, & Wang, 2014), while two studies found opposite effects (Themanson et al., 2014; Saunders et al., 2018). Related, Inzlicht and Al-Khindi (2012) used a misattribution procedure to assess the effect of affective states on error monitoring. More precisely, the authors speculated that participants should discount a negative affective response to errors in a condition in which they believed that they would experience negative affect that was unrelated to conflict. Although their study found evidence for a reduced ERN in this condition compared to control, two recent follow-up studies failed to replicate the finding (Cano Rodilla, Beauducel, & Leue, 2016; Elkins-Brown, Saunders, & Inzlicht, 2018).

Five studies investigated a modulation of N2/N450 responses, and only one of them found that tonic negative valence increased the N2 (Otten & Jonas, 2014), while two studies found the opposite effect (Nixon et al., 2013; Yuan et al., 2011) and the others reported null-effects (Clayson et al., 2011).

A few studies induced phasic affect with presentations of affective stimuli prior to each trial. Wiswede, Münte, Goschke, and Rüsseler (2009) reported increased ERNs in a flanker task following negative affective pictures (but no effect on the N2). A study by Boksem, Ruys, and Aarts (2011) found increased ERNs after presentation of disgusting faces relative to neutral faces. However, sad faces did not produce an effect relative to neutral faces. Furthermore, Larson, Perlstein, Stigge-Kaufman, Kelly, and Dotson (2006) obtained an increased ERN following positive affective pictures, in contradiction to the prediction that negative affect should enhance the ERN response. Roh, Chang, and Kim (2016) found no such effect in healthy participants, but an increased ERN to fearful faces in patients with obsessive compulsive disorder. Results with measurements of the N2/N450 response were more univocal. Here several studies reported an increased N2/N450 response after presentations of negative and positive (compared to neutral) words prior to flanker or Simon task trials (Kanske & Kotz, 2010, 2011a, 2011b, 2011c; Xue, et al., 2013; Zhang, Teo, & Wu, 2018; stop-signal task: Senderecka, 2016; but see Li et al., 2014 for a failure to replicate). In sum, evidence for tonic and phasic affective influences on monitoring is rather ambiguous.

2.4 Conflict-triggered affect drives control adaptation – the affect ▶ control link

According to the affective signaling hypothesis, conflict-triggered negative affect serves as a learning signal for control adaptation. As described above in more detail, most studies indexed adaption of control with the sequential congruency effect. In this part, evidence is reviewed that investigated the relationship between negative affect and the size of the sequential congruency effect (for an overview see Table 3). We will first describe studies that tested a correlation between affective traits and the sequential congruency effect. If conflict-triggered negative affect drives conflict adaptation, the sequential congruency effect should be increased for persons that experience more negative affect. Then, we will review studies that experimentally manipulated tonic or phasic affects and tested the prediction that induction of negative affect should increase the negative learning signal for control adaptation and result in a larger sequential congruency effect.

2.4.1 Correlational evidence for the affect ▶ control link

Some studies suggested that sequential congruency effects are increased for participants with high anxiety (Booth & Peker, 2017; Larson, Clawson, Clayson, & Baldwin, 2013). However, this link between the sequential congruency effect and anxiety has not been replicated by others (Gold, Jarcho, Rosen, Pine, & Ernst, 2015; Krug & Carter, 2010; Osinsky, Alexander, Gebhardt, & Hennig, 2010; Osinsky, Gebhardt, Alexander, & Hennig, 2012). Results for mood disorders are also mixed. Two studies found that participants with depression produce stronger sequential congruency effects (van Steenbergen, Booij, Band, Hommel, & van der Does, 2012; Larson, Clawson, Clayson, Baldwin, 2013), whereas others found no difference (Clawson, Clayson, & Larson, 2013; West, Choi, & Travers, 2010) or the reversed pattern (Holmes & Pizzagalli, 2007).

Another study found that sequential congruency effects were stronger for participants who score high in alertness (as indexed by the attentional network test; Liu, Yang, Chen, Huang, & Chen, 2013). De Galan and colleagues showed that participants who scored high on the cognitive dimension of alexithymia, which is associated with difficulties to identify and express or describe own emotions, show reduced sequential congruency effect (de Galan, Sellaro, Colzato, & Hommel, 2014; see also Maier, Scarpazza, Starita, Filogamo, & Ladavas, 2016 for related evidence regarding the ERN).

2.4.2 Experimental evidence for the affect ▶ control link

Many studies reported an affective modulation of control by tonic affect. Studies induced mood states with movie clips (Schuch & Koch, 2015); music and imagination (van Steenbergen, Band, & Hommel, 2010); cartoons (van Steenbergen, Band, Hommel, Rombouts, & Nieuwenhuis, 2015); approach/avoidance gestures (Hengstler, Holland, van Steenbergen, & van Knippenberg, 2014); mock feedback on intelligence tests (Schuch, Zweerings, Hirsch, & Koch, 2017; Schuch & Pütz, 2018) or on task performance (Yang & Pourtois, 2018) or particular screen colors (Wang, Zhao, Xue, & Chen, 2016). These studies consistently found that negative mood states increase sequential congruency effects, while positive mood states decrease sequential congruency effects.

For induction of phasic affect, studies intermixed presentations of affective stimuli (pictures, words, monetary rewards, etc.) at the time of presentation of the target or between trials. Van Steenbergen and colleagues observed a reduced sequential congruency effect following a (performance non-contingent) reward signal relative to a loss signal (van Steenbergen, Band &, Hommel, 2009; see also van Steenbergen et al., 2012). They concluded that the reward signal was opposed to the negative conflict signal and therefore impaired control adaption. However, other experiments failed to reproduce this effect (Stürmer, 2011, Exp. 1; Yamaguchi & Nishimura, 2018, Exp. 2 & 3). Another study included high-arousing unpleasant and pleasant stimuli and found no difference in the magnitude of the sequential congruency effects for unpleasant and pleasant stimuli; however, the sequential congruency effect was increased by high arousal relative to a baseline condition with neutral stimuli (Zeng et al., 2016). This research suggests that arousal is more influential than affective valence for sequential congruency effect. However, a study that varied the arousal level systematically within each valence category observed no effect of valence and arousal on the size of sequential congruency effects in a Simon task (Dignath, Janczyk, & Eder, 2017). Finally, increasing arousal more directly via vagus nerve stimulation (relative to a sham stimulation) resulted in larger sequential congruency effect than under sham treatment (Fischer, Ventura-Bort, Hamm, & Weymar, 2018).

In contrast to the research reviewed above, another line of research suggests that high arousal/negative affect decreases the size of the sequential congruency effect. Padmala, Bauer, and Pessoa (2011) reported that presentations of negative pictures between trials eliminated the sequential congruency effect (relative to presentations of neutral pictures). The authors suggested that negative stimuli high in arousal draw attention away and occupy resources needed for control adaptation processes. This explanation is in line with other research showing that arousing accessory tones presented between trials reduced the sequential congruency effect in a Stroop task compared to a neutral baseline (Soutschek, Müller, & Schubert, 2013, Exp. 2). However, it should be noted that this effect was not replicated in the Simon task (Böckler, Alpay, & Stürmer, 2011; Soutschek et al., 2013, Exp. 1). Another study observed a reduced sequential congruency effect (relative to a neutral baseline) when cues associated with a reward or loss were presented simultaneously with the target (Becker, Jostmann, & Holland, 2018). Negative arousal, induced by a processing fluency manipulation of target stimuli in a flanker or Stroop task, also diminished the sequential congruency effect relative to a condition with low arousing, positive affect (Fritz, Fischer, & Dreisbach, 2015). A different research approach has been taken by a recent study by Fröber et al. (2017) who showed that the congruency effect is reduced following trials that were evaluated negatively by the participants. In this study, however, the experimenter had no control over the participants´ affective ratings that were more negative for incongruent trials on average.

Summary of the literature review

Results from a large set of studies across different tasks and with a variety of affect measures support the conflict ▶ affect link and show that conflict and errors trigger negative affect. Regarding the affect ▶ monitoring link, correlational evidence is in line with the idea that the affective consequences of conflict/ errors are monitored, although such an approach is clearly limited. However, experimental evidence is rather mixed. More specifically, it remains unclear how the induction of tonic and phasic affect influences the N2 and the ERN. Studies that addressed the affect ▶ control link provided some evidence for a link between negativity and increased sequential congruency effect. Experimental studies showed the most direct evidence that negative tonic affect increases the sequential congruency effect, which supports the idea that control adaptation is dependent on negative affect. However, this conjecture is not supported by the ambiguous results of those studies that induced phasic affect. Together, the literature review showed that while some key predictions of the affective signaling hypothesis have been confirmed, others still require more empirical testing.

3. Affective signaling – Challenges and future directions

The previous parts of this review article summarized research on the affective signaling hypothesis. Together, it showed that not all predictions of the affective signaling hypothesis were supported by available evidence. Do these inconsistencies falsify the affective signaling hypothesis? Not necessarily, and this is due to the epistemological status of the affective signaling hypothesis that refers more to a theoretical framework (that is consistent with a body of data), than to a testable theory (that can be falsified by a single experiment). In the context of discovery, this under-specification has a heuristic value and can stimulate new research which is evidenced by the number of studies reviewed here. However, frameworks that specify global principles can also inspire more specific local theories that allow for a rigorous test and falsification. The next part of this article identifies several starting points for such local theories by discussing challenges and strategies for future research on the affective signaling hypothesis.

3.1 Specifying the role of resolved conflict and affect.

An important question is whether the conflict signal is best characterized by a negative affective state or by a transition from a negative to a positive affective state. Schouppe and colleagues (2015) showed that responding to an incongruent (flanker or Stroop) trial facilitated classifications of positive words relative to negative words (for a replication see Ivanchei et al., 2018). According to this research, conflict resolution triggers positive affect. In support of this idea, Schouppe and colleagues suggested that results of a previous study by Fritz and Dreisbach (2015) could also be explained by positive affect following conflict resolution (Schouppe et al., 2015, p. 259). In this study, prolonged (passive) viewing of incongruent Stroop stimuli causes more positive evaluation in the AMP, possibly because participants resolved the conflict during the waiting period (for an analogous finding with the affective priming paradigm see Pan, Shi, Lu, Wu, Xue, & Li, 2016, Exp. 2). Further correlational evidence comes from a study that found an increased sequential congruency effect for participants high in achievement motivation – a motive that affects motivational engagement in and positive experience of challenging tasks. This research suggests that resolution of conflict was particularly rewarding for participants high in achievement motive, which affected the size of conflict adaptation (Zhao, Jia, & Maes, 2018).

However, it remains unclear how these results relate to studies that observed negative affect after conflict in tasks in which participants actively responded to conflict (see the column “response to conflict” in Table 1). In a direct test between groups of participants who were actively responding a Stroop task and participants who were passively observing color words, Damen and colleagues observed no difference of affective evaluations between groups (Damen et al., 2018). More specifically, both active and passive groups showed more negative evaluations in the AMP following conflict. Accordingly, these findings do not support the hypothesis that actively resolved conflict is evaluated as positive.

Therefore, future research should systematically manipulate the response mode (active vs. passive) in response-interference tasks to investigate conditions under which active responses to conflict changes the affective evaluation of conflict. Furthermore, more compelling evidence is needed for the hypothesis that conflict detection and resolution can be described by a transition of conflict-triggered affect from (initially) negative to more positive affect (following successful responding). Here, continuous physiological measures of affect like Electromyography could provide a window into the on-line dynamics of conflict and response-triggered affect (cf. Dimberg, Thunberg, & Elmehed, 2000).

3.2 Tweaking manipulations of phasic affect.

As discussed in detail before, results of phasic affect manipulations on the sequential congruency effect were ambiguous. These manipulations are based on the logic that phasic affect triggered by task-irrelevant stimuli should modulate the strength of the affective signal evoked by conflict (cf. van Steenbergen et al., 2009). However, this situation creates an affective credit assignment problem: How can the cognitive system know whether a given signal was triggered by conflict or whether it was triggered by an irrelevant event (Schuch, Dignath, Steinhauser, & Janczyk, 2018)? Possibly, confusion of task-relevant (conflict-triggered) and -irrelevant (stimulus-triggered) affect can account for the heterogeneity of results in this research area. Conflict-triggered compared to stimulus-triggered affect might also be associated with different appraisal patterns--and hence cause different emotions (cf. Scherer & Moors, 2019): While the former state is attributed to one's own action, the latter state is explained with external events. If this conjecture is correct, factors that facilitate or impair the assignment of an affective state to its source should moderate how affective stimuli influence the sequential congruency effect. For example, temporal separation between two events should modulate the likelihood that affective information of these sources becomes integrated. Indeed, if affective stimuli and task-related stimuli were presented simultaneously, studies observed increased sequential congruency effects with affective stimuli (Zeng et al., 2017). In contrast, if affective stimuli and task-related stimuli were presented separately, studies observed no influence of affective stimuli on the sequential congruency effect (Dignath et al., 2017). Hence, more research is warranted that directly addresses how the timing of affective stimuli impacts the sequential congruency effect.

However, even if the affect resulting from conflict and task-irrelevant stimuli is combined, the outcome of this combination remains unclear. While some studies assume that positive affective stimuli decrease the negativity of conflict (cf. van Steenbergen et al., 2009), research on ‘hedonic contrast’ suggests that positive stimuli can also act as a background against which the registration of negative conflict is facilitated (Eder & Dignath, 2014; Larsen & Norris, 2009). Indeed, studies showed that conflict in a context-specific learning paradigm was enhanced when presented together with positive compared to negative stimuli (Dreisbach, Reindl, & Fischer, 2016; Dreisbach, Fröber, Berger, & Fischer, 2018; but see Zhang, Kiesel, & Dignath, 2019, for a null-effect). Clearly, more research is needed to get a better understanding of when and how task-irrelevant affect merges with task-relevant conflict-triggered affect.

Throughout this review, we adopted a dimensional view of affect (Barrett & Russell, 1999) and conceptualized affect as a mixture of valence and arousal. However, theoretically it might be important to differentiate between both dimensions. For instance, Verguts and Notebaert suggested a model that accounts for control adaptation with states of high arousal. According to this theory, high arousal states promote feature binding between task-relevant stimuli and responses (Verguts & Notebaert, 2009; Abrahamse, Braem, Notebaert, & Verguts, 2016). The majority of studies examined a contribution of arousal by comparison of high-arousing negative and positive stimuli against low arousing neutral stimuli (see Table 2 and 3 for an overview). However, it has been also suggested that valence and arousal can influence affective reactions in an interactive fashion (Eder & Rothermund, 2010; Robinson, Storbeck, Meier, & Kirkeby, 2004), and only few studies manipulated the valence and arousal of stimuli orthogonally (van Steenbergen et al., 2010; Dignath et al., 2017). More generally, the effect of affective stimuli on attention is caused by the interaction between properties of stimuli and the individuals‘ appraisal patterns (e.g., Bosch, Sander, Pourtois, & Scherer, 2008; Wentura, Müller, Rothermund, 2013; Vogt, Lozo, Koster, De Houwer, 2011).

3.3 Testing the causal role of affect for cognitive control.

Central to the affective signaling hypothesis is the idea that conflict-triggered affect is *causal* for control adaptation. However, available evidence does not rule out the possibility that conflict-triggered affect is an epiphenomenon or that the influence of affect on cognitive control is more indirect. For instance, Fröber and colleagues (2017) examined a causal role of affect for conflict adaptation and observed increased sequential congruency effect in trials that were rated as unpleasant relative to trials that were rated as rather pleasant. However, subjective ratings of trials in conflict tasks are influenced by the magnitude of experienced conflict (cf. Abrahamse & Braem, 2015; Foerster, Pfister, Reuss, & Kunde, 2017). Accordingly, it is possible that those trials with a high level of conflict also triggered more control adaption in addition to, and independently of, ratings of unpleasantness. Future research could follow-up on this task design, for instance by measuring EMG as an unobtrusive trial-to-trial assessment of affect in combination with mediation analysis. More specifically, one could hypothesize that the relationship between the congruency effect in trial N-1 and the reduction of the congruency effect in trial N (i.e., the magnitude of sequential congruency effect) is mediated by the strength of EMG activity of the corrugator supercilii muscle (indicating negative affect). Relatedly, such online assessment of affective responses to conflict allows for a unobstrusive manipulation check of conflict-induced affect that does not interfere with conflict adaptation (in contrast to explicit ratings).

An alternative research strategy would be to directly change affect or arousal and assess the influence of this manipulation on control adaptation. Previous research already showed that increasing arousal via the locus coeruleus-noradrenaline (LC-NE) system by means of vagus nerve stimulation increased control adaptation (Fischer et al., 2018). Here future research could use psychopharmacological interventions to show that reduced affect is accompanied by a reduction in monitoring and control adaptation (see Randles, Kam, Heine, Inzlicht, & Handy, 2016). Finally, research on error monitoring showed that a down-regulation of negative emotions reduced the ERN (Moser, Most, & Simons, 2010; Hobson, Saunders, Al-Khindi, & Inzlicht, 2014). Future research may, therefore, use explicit emotion regulation strategies to modulate control adaptation. More specifically, one would expect a down-regulation of negative affective states to decrease the size of the sequential congruency effect.

3.4 Disentangling the role of binding and control adaptation.

The interpretation of the affect ▶ control link is complicated by the fact that the sequential congruency effect in many reviewed studies can be alternatively explained with feature binding (Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003). According to a feature binding account, the sequential congruency effect reflects the costs/benefits to retrieve stimulus and response links from episodic memory. For instance, in a flanker task with two responses and two stimuli, target and distractor are repeated in two consecutive trials in half of the congruent trials (complete repetition), while they change across two consecutive trials in half of the incongruent trials (complete alternation). In the remaining trials with transitions from incongruent to congruent (or vice versa), either the target or the distractor is repeated (partial repetitions). It is known that partial repetitions require considerably more time than complete alternations or complete repetitions because in the first case two different event files must compete for the same feature, whereas in the latter cases two distinct event files are used (for an overview see Henson, Eckstein, Waszak, Frings, & Horner, 2014).

Particularly relevant in the present context is the observation that binding of stimulus and response features is weakened by negative affect (Colzato, Van Wouwe, & Hommel, 2007; for similar evidence regarding more sustained stimulus-response binding, see Waszak & Pholulamdeth, 2009). Therefore, some of the reviewed affective modulations of the sequential congruency effect could also reflect the interplay of binding and affect and not necessarily indicate an affective modulation of control. One way to address this problem would be to eliminate feature repetitions with confound-minimized task designs in which participants switch between two distinct stimulus-responses sets (e.g., Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Kim & Cho, 2014; Schmidt & Weissmann, 2014; Dignath, Johannsen, Hommel, & Kiesel, in press).

3.5 Differentiating between conflict and errors.

For our discussion, we used conflict monitoring theory and assumed that errors and conflicts are comparable events (Yeung et al., 2004). It is parsimonious to assume that the affective nature of errors is a consequence of the underlying conflict. However, there are also arguments that error processing is not identical to conflict processing. First, there is evidence that errors activate brain areas, such as the amygdala (Koban & Pourtois, 2010) or the anterior insula (Ullsperger, Harsay, Wessel, & Ridderinkhof, 2010), in addition to the dACC. Source modelling also revealed neural generators of the ERN response in the orbitofrontal cortex, suggesting that the neural substrate of error monitoring and conflict monitoring are not identical (Buzzell et al., 2017) and that activity in these regions could be responsible for an affective tagging of errors, but not of conflict (Koban & Pourtois, 2014). Second, an influential theory of error processing explained the ERN response with a reward prediction error that is neurally implemented by the dopaminergic system (Holroyd & Coles, 2002). This account can explain why the ERN is sensitive to manipulations of the monetary value of errors (in addition to manipulations of error expectancy) (Ganushchak & Schiller, 2008; Hajcak, Moser, Yeung, & Simons, 2005; Maier & Steinhauser, 2013). Negative reward prediction errors could itself be viewed as aversive signals and could have caused some of the results described in the previous sections. Third, conscious awareness of errors is accompanied by the error positivity, a specific neural signature that can be differentiated from the ERN (Falkenstein et al., 1990). In theory, the error positivity can be explained in terms of evidence accumulation (Steinhauser & Yeung, 2010) and has not been linked to conflict processing. Interestingly, several studies showed a correlation between the size of the error positivity (but not the ERN) and the negativity of an error (as indicated by physiological measures of affect and arousal; see Elkins-Brown, Saunders, & Inzlicht, 2016; Hajcak et al., 2003; O'Connell et al., 2007; Wessel, Danielmeier, & Ullsperger, 2011). Thus, it remains possible that the negative affective consequences that follow after an error are not directly related to the ERN as suggested by the affect ► monitoring link.

4. Summary

The current article reviewed evidence related to an affective extension of the conflict monitoring theory. This affective signaling hypothesis proposes (i) that conflict triggers negative affect (ii) which is registered by a dedicated monitoring system and (iii) serves as a signal for control adaptation. Based on studies that combined response-interference tasks with affective measures we concluded that (i) the conflict ► affect link is well supported by empirical evidence. Studies that assessed affective influences on neural markers of performance monitoring provide mostly correlational evidence in favor for (ii) the affect ▶ monitoring link, while experimental evidence is ambiguous. Finally, studies that probed affective influences on the sequential congruency effect provide supporting evidence for (iii) the affect ▶ control when considering tonic affect, while studies that assess influences of phasic affect on the sequential congruency effect are having mixed implications. Therefore, the present review concluded that the affective signaling hypothesis is supported by a substantial amount of evidence, but also points out areas that require more attention in order to develop a more comprehensive account of the interaction between affect and control.

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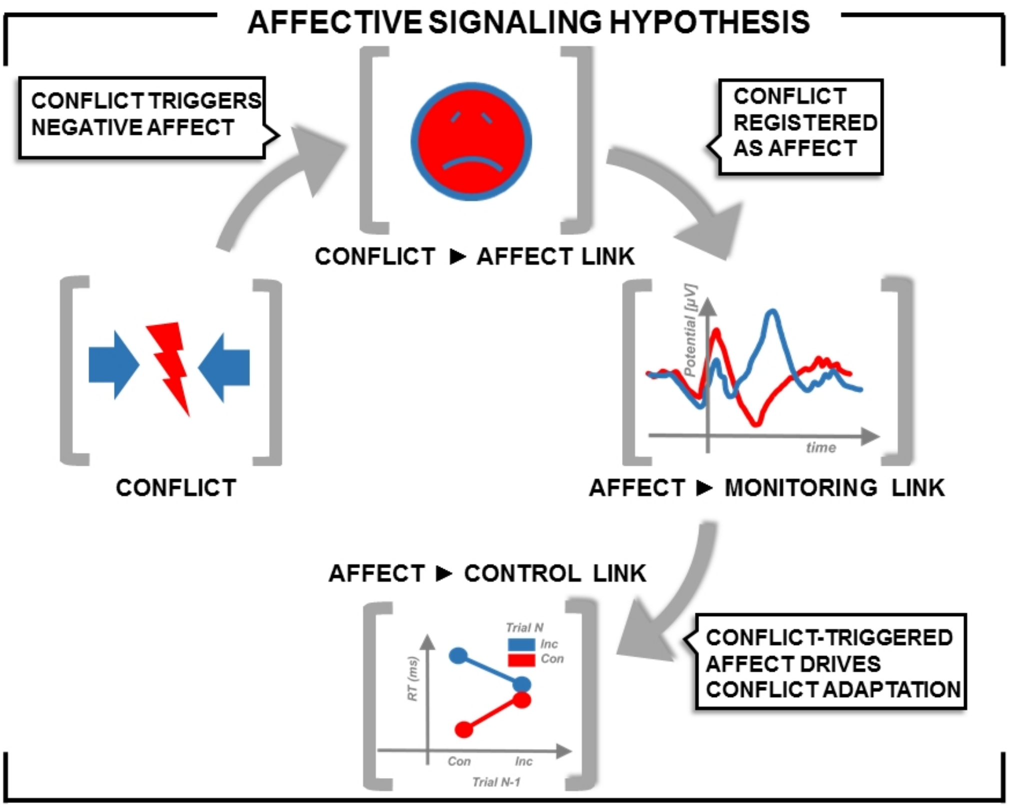

Figure 1. Schematic illustration of the affective signaling hypothesis. Conflict between responses (left) triggers a brief negative affective reaction (top: I. the conflict ► affect link). The review describes several dependent measures that assess the affective consequences of conflict and errors. This conflict/error-triggered affect is supposed to be detected by a monitoring system (right: II. the affect ► monitoring link; the N2 (blue) and the ERN (red) provide online measures of conflict/error monitoring). Subsequently, this signal is used for adaptive changes in attention and performance (bottom: III. the affect ► control link; the sequential congruency effect provides a measure of adaptation to conflict). As a consequence, conflict following previous conflict is reduced and resulting affective responses are less negative.

Table 1 Data from studies that investigated affective consequences of conflict and errors (the conflict ► affect link).

Reference	Task	Response to conflict	DV affect	Finding
Aarts, et al., 2012	Go/NoGo	yes	affective priming	error: ↓ RT (neg)
Aarts, et al., 2013	Go/NoGo	yes	affective priming	error: ↓ RT (neg)
Botvinick & Rosen, 2009, Exp. 1	task switching	yes	task choice	context (high inc): ↓ choices & ↑ SCR
Botvinick & Rosen, 2009, Exp. 2	task switching	yes	task choice	context (high inc): ↓ choices & ↑ SCR
Botvinick et al., 2009	task switching	yes	task choice	context (high inc): ↓ choices
Braem et al., 2017	task switching	yes	fMRI	inc: ↓ ACC response to negative pictures
Brouillet et al., 2011	grasp-CE	no	affective priming	inc: ↓ RT (neg)
Buttaccio & Hahn, 2010	Go/NoGo	yes	rating of target	NoGo: ↑ rating (neg)
Chetverikov et al., 2017	flanker	yes	rating of target & distractor	error: ↑ rating (neg); no inc-effect
Damen et al., 2018, Exp. 1	Stroop	no	AMP	inc: ↑ rating (neg)
Damen et al., 2018, Exp. 2	Stroop	no/yes	AMP	inc: ↑ rating (neg) for active and passive Stroop
Damen et al., 2018, Exp. 3	Stroop	no/yes	AMP	inc: ↑ rating (neg) for active and passive Stroop
Damen et al., 2018, Exp. 4	Stroop	no/yes	AMP	inc: ↑ rating (neg) for active and passive Stroop
De Saedeleer & Pourtois, 2016, Exp. 1	Go/NoGo	yes	affective priming	error: ↓ RT (neg)
De Saedeleer & Pourtois, 2016, Exp. 2	Go/NoGo	yes	affective priming	error: ↓ RT (neg)
Desender et al., 2017, Exp. 1	prime-target	yes	task choice	context (high inc): ↓ choices
Desender et al., 2017, Exp. 2	prime-target	yes	task choice	context (high inc): ↓ choices
Desender et al., 2017, Exp. 3	prime-target	yes	task choice	context (high inc): ↓ choices
Dignath & Eder, 2015, Exp. 1	Stroop	no	approach avoidance task	inc: ↑ choices (avoidance)
Dignath & Eder, 2015, Exp. 2	Stroop	no	approach avoidance task	inc: ↓ RT (avoidance) & ↑ choices (avoidance)
Dignath & Eder, 2015, Exp. 3	Stroop	no	approach avoidance task	inc: ↓ RT (avoidance) & ↑ choices (avoidance)

(continued on next page)

Table 1 continued.

Reference	Task	Response to conflict	DV affect	Finding
Dignath et al., 2015, Exp. 1	Simon & flanker	yes	task choice	inc: ↑ switchrate
Dignath et al., 2015, Exp. 3	Simon & flanker	yes	task choice	inc: ↑ switchrate
Doallo et al., 2012	Go/NoGo	yes	rating of target	NoGo: ↓ rating (trust)
Dreisbach & Fischer, 2012	Stroop	no	affective priming	inc: ↓ RT (neg)
Dunn et al., 2018	task switching	yes	task choice	context (high inc): ↓ choices
Elkins-Brown et al., 2016	Go/NoGo	yes	EMG	error: ↑ (corrugator supercilii)
Elkins-Brown et al., 2017, Exp. 2	flanker	yes	EMG	error: ↑ (corrugator supercilii)
Fenske et al., 2005	Go/NoGo	yes	rating of target	NoGo: ↓ rating (trust)
Ferrey et al., 2012, Exp. 1	Go/NoGo	yes	rating of target	NoGo: ↓ rating (attractivity)
Ferrey et al., 2012, Exp. 2	Go/NoGo	yes	rating of target	NoGo: ↓ rating (attractivity)
Fiehler et al., 2004	flanker	yes	heart rate	inc & error: ↓ heartrate
Frischen et al., 2012, Exp. 1	Go/NoGo	yes	rating of target	NoGo: ↓ rating (trust)
Frischen et al., 2012, Exp. 2	Go/NoGo	yes	rating of target	NoGo: ↓ rating (attractivity)
Frischen et al., 2012, Exp. 3	Go/NoGo	yes	rating of target	NoGo: ↓ rating (liking)
Frischen et al., 2012, Exp. 4	Go/NoGo	yes	rating of target	NoGo: ↓ rating (liking)
Fritz & Dreisbach, 2013	Stroop	no	AMP	inc: ↑ rating (neg)
Fritz & Dreisbach, 2015, Exp. 1	Stroop	no	AMP	inc: ↑ Rating (neg) with short SOA
Fritz & Dreisbach, 2015, Exp. 2	Stroop	no	AMP	inc: ↑ Rating (neg) with short SOA
Fritz & Dreisbach, 2015, Exp. 3	Stroop	no	AMP	inc: ↑ Rating (neg) with short SOA
Fröber et al., 2017	Simon	yes	rating of trials	inc: ↑ Rating (neg)
Gold et al., 2015, Exp. 1	task switching	yes	task choice	context (high inc): ↓ choices
Gold et al., 2015, Exp. 2	task switching	yes	task choice	context (high inc): no effect

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Table 1 continued.

Reference	Task	Response to conflict	DV affect	Finding
Gold et al., 2015, Exp. 3	task switching	yes	task choice	context (high inc): ↓ choices
Goller et al., 2017, Exp. 1	flanker	yes	AMP	inc: ↑ rating (neg), only subliminal
Goller et al., 2017, Exp. 2	flanker	yes	AMP	inc: ↑ rating (neg), only subliminal
Goller et al., 2017, Exp. 3	flanker	yes	AMP	inc: ↑ rating (neg), only subliminal
Hajcak & Foti, 2008	flanker	yes	startle	error: ↑ startle
Hajcak et al., 2003	Stroop	yes	SCR, heartrate	error: ↑ SCR & ↓ heartrate; inc: no effect
Hajcak et al., 2004	Stroop	yes	SCR, heartrate	error: ↑ SCR & ↓ heartrate; inc: no effect
Hatukai & Algom, 2017, Exp. 7	Stroop	yes	affective-mapping task	inc: ↓ RT (neg)
Hochman et al., 2017, Exp. 1	flanker	yes	force of key-release	error: ↑ force of keyrelease
Hochman et al., 2017, Exp. 2	flanker	yes	RT of key-release	error: ↓ RT keyrelease
Ivanchei et al., 2018	flanker	yes	affective priming	inc & error: ↓ RT (neg)
Kiss et al., 2008	Go/NoGo	yes	rating of target	NoGo: ↓ rating (trust)
Kobayashi et al., 2007, Exp. 1	Stroop	yes	SCR	inc & error: ↑ SCR
Kobayashi et al., 2007, Exp. 2	Stroop	yes	SCR	inc & error: ↑ SCR
Kool et al., 2010, Exp. 1	task switching	yes	task choice	context (high inc): ↓ choices
Kool et al., 2010, Exp. 3	task switching	yes	task choice	context (high inc): ↓ choices
Kool et al., 2010, Exp. 5	task switching	yes	task choice	context (high inc): ↓ choices
Kool et al., 2013	task switching	yes	task choice	context (high inc): ↓ choices
Kuipers et al., 2017	flanker	yes	heart beta-adrenergic activity	inc: ↑ beta-adrenergic activity
Ligeza & Wyczesany, 2017	flanker	yes	EEG for pictures	inc: ↑ late positive potential (neg)
Lindström et al., 2013	Go/NoGo	yes	EMG	error & high inc: ↑ (corrugator supercilii)
Martiny-Huenger et al., 2014, Exp. 1	flanker	yes	rating of target & distractor	inc: ↑ rating (neg)

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Table 1 continued.

Reference	Task	Response to conflict	DV affect	Finding
Martiny-Huenger et al., 2014, Exp. 2	flanker	yes	rating of Target & Distractor	inc: ↑ rating (neg)
McGuire & Botvinick, 2010, Exp.1	task switching	yes	task choice	context (high inc): ↓ choices
McGuire & Botvinick, 2010, Exp.2	task switching	yes	task choice	context (high inc): ↓ choices
Morsella et al., 2009, Exp. 1	Stroop	yes	post experimental questions	inc: ↑ rating (avoidance)
Morsella et al., 2009, Exp. 2	Stroop	yes	post experimental questions	inc: ↑ rating (avoidance)
Naccache et al., 2005, Exp. 9	Stroop	yes	SCR	inc: ↑ SCR
Pan et al., 2016, Exp. 1	Stroop	no	affective priming & EEG	inc: ↓ RT (neg); ↑ N400 (neg)
Regenberg et al., 2012, Exp. 1	grasp-CE	yes	AMP	inc: ↑ rating (neg)
Regenberg et al., 2012, Exp. 2	grasp-CE	yes	rating of trials	inc: ↑ rating (neg)
Renaud, & Blondin, 1997	Stroop	yes	SCR	inc: no SCR effect
Riesel et al., 2013	flanker	yes	startle	error: ↑ startle
Sayalı & Badre, 2019, Exp.1	task switching	yes	task choice	context (high inc): ↓ choices
Sayalı & Badre, 2019, Exp.2	task switching	yes	task choice	context (high inc): no effeect
Schacht et al., 2010	Go/NoGo & Simon	yes	SCR, startle	NoGo: ↓ startle & ↓ SCR; Simon: no effect
Schacht et al., 2009, Exp. 1	Go/NoGo	yes	EMG, SCR	NoGo: ↑ (corrugator supercilii) & ↓ SCR
Schacht et al., 2009, Exp. 2	Go/NoGo	yes	EMG, SCR, startle	NoGo: ↑ (corrugator supercilii) & ↓ startle
Schacht et al., 2009, Exp. 4	Go/NoGo	yes	EMG, SCR, startle	NoGo: ↑ (corrugator supercilii) & ↓ startle & ↓ SCR
Schouppe et al., 2014	flanker	yes	task choice	context (high inc): ↓ choices
Schouppe et al., 2015, Exp. 1	flanker	no	affective priming	inc: ↓ RT (neg)
Schouppe et al., 2015, Exp. 2	flanker & Stroop	yes	affective priming	inc: ↑ RT (neg)
Schouppe et al., 2012	Stroop	no	approach avoidance task	inc: ↓ RT (avoidance)

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Table 1 continued.

Reference	Task	Response to conflict	DV affect	Finding
Schupp et al., 1994, Exp.1	Go/NoGo	yes	startle	NoGo: ↓ startle
Schupp et al., 1994, Exp.2	Go/NoGo	yes	startle	NoGo: ↓ startle
Spruit et al., 2018	flanker &di task switching	yes	heart beta-adrenergic activity	error: ↑ beta-adrenergic activity
Spunt et al., 2012	stop-signal	yes	rating of trials	inc: ↑ Rating (neg)
Ian der Veen et al., 2000	Go/NoGo	yes	heart rate	inc: ↓ heartrate
Vermeylen et al., 2019, Exp. 1	task switching	yes	AMP	inc: ↑ RT (neg)
Vermeylen et al., 2019, Exp. 2	task switching	yes	AMP	inc: ↑ RT (neg)
Waid & Orne, 1982	Stroop	yes	SCR	inc: ↑ SCR
van der Wel & van Steenbergen, 2018	review	yes	pupil diameter	inc: ↑ pupil diameter

Note: RT = reaction time; SCR = skin conductance response; inc = incongruent; neg = negative; grasp-CE=grasp-compatibility effect; EMG = electromyogram; AMP = affective misattribution procedure; EEG = Electroencephalogram

Table 2 Data from studies that investigated affective modulation of the N2 and ERN (the affect ► monitoring link).

Reference	Task	Affect induction	Design	Manipulation	Finding
Böckler et al., 2011	Simon	phasic	experimental	accessory tone	Δ(inc-con) N2: arousal = no-arousal
Boksem et al., 2011	Simon	phasic	experimental	faces	ERN (disgusted) > ERN (happy, sad)
Elkins-Brown et al., 2018	Go/NoGo	phasic	experimental	missattribution	ERN (missattribution) = ERN (control)
Inzlicht & Al-Khindi, 2012	Go/NoGo	phasic	experimental	missattribution	ERN (missattribution) < ERN (control)
Kanske & Kotz, 2010	flanker	phasic	experimental	words	Δ(inc-con) N2: (neg) > (neu)
Kanske & Kotz, 2011a	Simon	phasic	experimental	words	Δ(inc-con) N2: (pos) > (neu)
Kanske & Kotz, 2011b	Simon	phasic	experimental	words	Δ(inc-con) N2: (neg) > (neu)
Kanske & Kotz, 2011c	flanker	phasic	experimental	words	Δ(inc-con) N2: (neg) > (neu)
Larson et al., 2006	flanker	phasic	experimental	pictures	ERN (pos) > ERN (neg, neu)
Li et al., 2014	flanker	phasic	experimental	words	no N2 effect
Cano Rodilla et al., 2016	Go/NoGo	phasic	experimental	missattribution	ERN (missattribution) = ERN (control)
Roh et al., 2016	flanker	phasic	experimental	faces	ERN (fearful) > ERN (neutral) in OCD patient, not in controls
Senderecka et al., 2018	stop signal task	phasic	experimental	words	no ERN effect
Senderecka, 2016	stop signal task	phasic	experimental	pictures	no ERN effect; N2 (neg) > N2 (neu)
Senderecka, 2018	stop signal task	phasic	experimental	sounds	no ERN effect
Wiswede et al., 2009	flanker	phasic	experimental	pictures	ERN (neg) > ERN (pos, neu); no N2 effect
Xue et al., 2013	Simon	phasic	experimental	faces	Δ(inc-con) N450: (pos) > (neu)
Zhang et al., 2018	flanker	phasic	experimental	words	Δ(inc-con) N2: (neg) > (neu)
Clayson et al., 2011	flanker	tonic	experimental	block-wise feedback	no ERN/N2 effects
Hobson et al., 2014	Go/NoGo	tonic	experimental	emotion regulation	ERN (down) < ERN (up, control), mediated by emotion ratings
Larson et al., 2013	flanker	tonic	experimental	music-imagination	no ERN effect (only CRN varied with arousal)

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Table 2 continued.

Reference	Task	Affect induction	Design	Manipulation	Finding
Moser et al., 2005	flanker	tonic	experimental	spider vs. ball in hand	no ERN effect
Nixon et al., 2013	Stroop	tonic	experimental	autobiographical scripts	N450 (sad) < N450 (control), no ERN reported
Olvet & Hajcak, 2011	flanker	tonic	experimental	movies	no ERN effect; change in mood predicted ERN
Otten & Jonas, 2014	Go/NoGo	tonic	experimental	social exclusion	N2 (exclusion) > N2 (inclusion), no ERN reported
Paul et al., 2017	Go/NoGo	tonic	experimental	imagery	no ERN effect, N2 not reported
Pfabigan et al., 2013	flanker	tonic	experimental	learned helplessness	ERN (helpless) > ERN (non-helpless), correlation ERN-helplessness
Saunders et al., 2018	Go/NoGo	tonic	experimental	affective touch	ERN (pos) > ERN (neu)
Themanson et al., 2014	flanker	tonic	experimental	social exclusion	ERN (exlusion) < ERN (inclusion) (pre-post)
Wang et al., 2014	Stroop	tonic	experimental	emotion regulation	EN(supp) < ERN(reapp, contr), no N450 effect
Wiswede et al., 2009	flanker	tonic	experimental	block-wise feedback	ERN (neg) > ERN (pos)
Wiswede et al., 2009	flanker	tonic	experimental	facial feedback	ERN (pos) < ERN (neu)
Yuan et al., 2011	Stroop	tonic	experimental	sounds	N450 (pos) > N450 (neu, neg)
Cavanagh & Shackman, 2015	meta-analysis	trait	correlational	/	↑ anxiety disorders & ↑ ERN & N2
Endrass & Ullsperger, 2014	review	trait	correlational	/	↑ OCD & ↑ ERN
Koban & Pourtois, 2014	review	trait	correlational	/	↑ negative affect & ↑ ERN
Meyer, 2017	review	trait	correlational	/	↑ anxiety disorders in children (6-18 years) & ↑ ERN
Moser et al., 2013	meta-analysis	trait	correlational	/	↑ anxiety disorders & ↑ ERN
Weinberg et al, 2015	review	trait	correlational	/	↑ negative affect & ↑ ERN

Note: inc = incongruent; con = congruent; neg = negative; pos = positive; neu = neutral; OCD = Obsessive Compulsive Disorder.

Table 3 Data from studies that investigated affective modulation of the sequential congruency effect (sequential congruency effect; the affect ► control link).

Reference	Task	Affect indcution	Design	Manipulation/ trait	FB control	Finding
Becker et al., 2018, Exp. 1	prime-target	phasic	experimental	gains/losses	post-hoc	SCE (neg |pos) < SCE (neu)
Becker et al., 2018, Exp. 2	prime-target	phasic	experimental	gains/losses	post-hoc	SCE (neg |pos) < SCE (neu)
Becker et al., 2018, Exp. 3	prime-target	phasic	experimental	gains/losses	a priori	SCE (neg |pos) < SCE (neu)
Böckler et al., 2011	Simon	phasic	experimental	accessory tone	no	SCE (arousal) = SCE (no-arousal)
Dignath et al., 2017, Exp. 1	Simon	phasic	experimental	pictures	no	SCE (neg, high) = SCE (neg, low) = SCE (pos, high) = SCE (pos, low)
Dignath et al., 2017, Exp. 2	Simon	phasic	experimental	pictures	no	SCE (neg, high) = SCE (neg, low) = SCE (pos, high) = SCE (pos, low)
Fischer et al., 2018	flanker	phasic	experimental	vagus nerve stimulation	post-hoc	SCE (arousal) > SCE (sham)
Fritz et al., 2015, Exp. 2	Stroop	phasic	experimental	fluency	post-hoc	SCE (neg) < SCE (pos)
Fritz et al., 2015 Exp. 1	flanker	phasic	experimental	fluency	post-hoc	errors: SCE (neg) < SCE (pos)
Padmala et al., 2011	Stroop	phasic	experimental	pictures	a priori	SCE (neg) < SCE (neu)
Soutschek et al., 2013, Exp. 1	Simon	phasic	experimental	accessory tone	post-hoc	SCE (arousal) = SCE (no-arousal)
Soutschek et al., 2013, Exp. 2	Stroop	phasic	experimental	accessory tone	post-hoc	SCE (arousal) < SCE (no-arousal)
Stürmer et al., 2011	Simon	phasic	experimental	gains/losses	no	SCE (neg) = SCE (pos) = SCE (neu)
van Steenbergen et al., 2009	flanker	phasic	experimental	gains/losses	no	SCE (neg) > SCE (pos)
van Steenbergen et al., 2012	flanker	phasic	experimental	gains/losses	no	SCE (neg) > SCE (pos)
Yamaguchi & Nishimura, 2018, Exp. 2	flanker	phasic	experimental	gains/losses	no	SCE (neg) = SCE (pos) = SCE (neu)
Yamaguchi & Nishimura, 2018, Exp. 3	flanker	phasic	experimental	gains/losses	no	SCE (neg) = SCE (pos) = SCE (neu)
Zeng et al. 2017, Exp. 1	flanker	phasic	experimental	words	no	SCE (neg | pos) > SCE (neu)
Zeng et al. 2017, Exp. 2	flanker	phasic	experimental	words	a priori	SCE (neg | pos) > SCE (neu)

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Table 3 continued.

Reference	Task	Affect indcution	Design	Manipulation/ trait	FB control	Finding
Hengstler et al., 2014, Exp. 1	flanker	tonic	experimental	approach/avoid. blockwise	no	SCE (neg) > SCE (pos)
Hengstler et al., 2014, Exp. 2	flanker	tonic	experimental	approach/avoid. blockwise	no	SCE (neg) > SCE (pos)
Hengstler et al., 2014, Exp. 3	flanker	tonic	experimental	approach/avoid. blockwise	a priori	SCE (neg) > SCE (pos)
Plessow et al., 2011	Simon	tonic	experimental	Trier Social Stress Test	post-hoc	errors: SCE (neg) < SCE (neu)
Schuch & Koch, 2015, Exp. 1	flanker	tonic	experimental	movies	post-hoc	errors: SCE (neg) > SCE (pos)
Schuch & Koch, 2015, Exp. 2	Stroop	tonic	experimental	movies	post-hoc	SCE (neg) > SCE (pos)
Schuch & Pütz, 2018	task-switch.	tonic	experimental	success/failure	post-hoc	task repetitions: SCE (neg) > SCE (pos)
Schuch et al., 2017, Exp. 1	flanker	tonic	experimental	success/failure	post-hoc	SCE (neg) > SCE (pos)
Schuch et al., 2017, Exp. 2	Stroop	tonic	experimental	success/failure	post-hoc	errors: SCE (neg) > SCE (pos)
van Steenbergen et al., 2010	flanker	tonic	experimental	music/imagination	no	SCE (neg) > SCE (pos)
van Steenbergen et al., 2015, Exp. 1	flanker	tonic	experimental	cartoons before block of trials	no	SCE (pos) < SCE (neutral)
van Steenbergen et al., 2015, pilot	flanker	tonic	experimental	cartoons before block of trials	no	SCE (pos) < SCE (neutral)
Wang et al., 2016, Exp. 1	flanker	tonic	experimental	background colour	a priori	SCE (low arousal) < SCE (medium & high arousal)
Wang et al., 2016, Exp. 2	flanker	tonic	experimental	background colour	a priori	SCE (low arousal) < SCE (medium & high arousal)

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Table 3 continued.

Reference	Task	Affect indcution	Design	Manipulation/ trait	FB control	Finding
Yang & Pourtois, 2018, Exp. 1	flanker	tonic	experimental	blocks with/ without contingent losses	no	SCE (neg) > SCE (neu)
Yang & Pourtois, 2020, Exp. 2	flanker	tonic	experimental	blocks with/ without contingent losses	apriori	SCE (neg) > SCE (neu)
Booth & Peker, 2017	Stroop	/	correlational	STAI	no	↑ STAI & ↑SCE
Clawson et al., 2013	flanker	/	correlational	BDI	no	no: BDI & SCE
de Galan et al., 2014	Simon	/	correlational	alexithymia	no	↑ alexithymia (cogn. dimension) & ↓SCE
Fröber et al., 2017	Simon	/	correlational	rating previous trial	no	negative rated trials & SCE (errors) ↓
Gold et al., 2015	Stroop	/	correlational	STAI	no	no: STAI & SCE
Holmes & Pizzagalli, 2007	Stroop	/	correlational	BDI	no	↓ BDI (negative feedback) & ↑SCE
Krug & Carter, 2010	Stroop	/	correlational	STAI	no	SCE does not correlate with STAI
Larson et al., 2013	flanker	/	correlational	STAI & BDI	no	↑ STAI & ↑SCE | ↑ BDI & ↑ SCE
Liu et al., 2013, Exp. 1	flanker	/	correlational	ANT	a priori	↑ alertness & ↑ SCE
Liu et al., 2013, Exp. 2	flanker	/	correlational	ANT	a priori	↑ alertness & ↑ SCE
Osinsky et al., 2010	Stroop	/	correlational	STAI	no	no: STAI & SCE
Osinsky et al., 2012	Stroop	/	correlational	STAI	no	no: STAI & SCE
van Steenbergen et al., 2012	Simon	/	correlational	MADRS	No	↑ MADRS & ↑ SCE
West et al., 2010	Stroop	/	correlational	BDI	no	no: BDI & SCE
Zhao et al., 2018, Exp. 1	flanker	/	correlational	motivation	No	↑ achievement motivation & ↑ SCE
Zhao et al., 2018, Exp. 2	flanker	/	correlational	motivation	a priori	↑ achievement motivation & ↑ SCE

Note: neg = negative; pos = positive; neu = neutral; avoid. = avoidance; SCE = sequential congruency effect; STAI = State-Trait Anxiety Inventory; BDI = becks-Depression-Index; ANT = Attentional-Network-Test; MADRS = Montgomery–Åsberg Depression Rating Scale.